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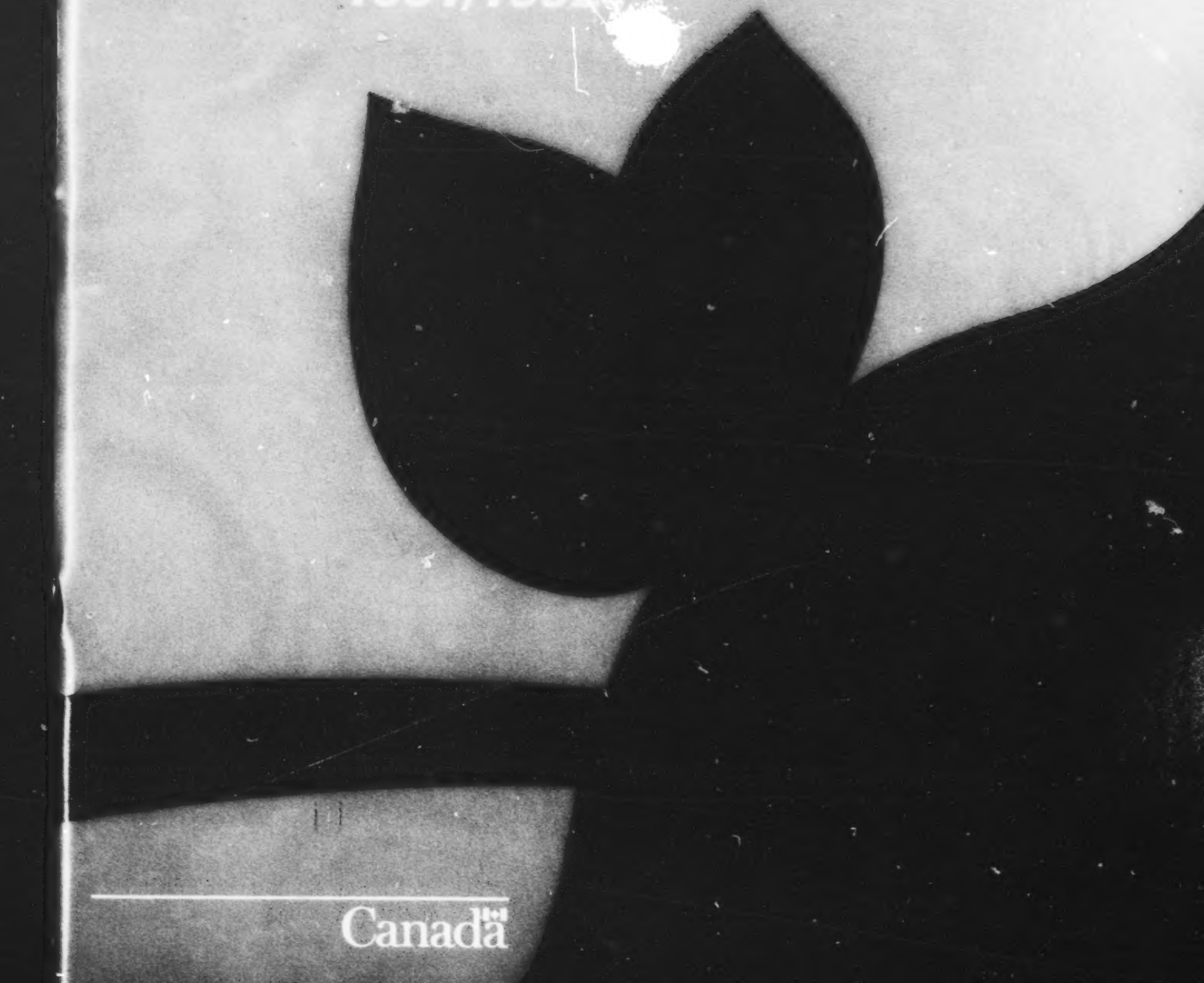
Plant Biotechnology Institute

Annual Report 1991/1992



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1. Vice-President's Foreword

The past year has witnessed a number of important events and advances that are helping to shape the future of biotechnology, both on the larger Canadian and international scene, and in the laboratories of NRC's biotechnology program.

In 1991-92, the nature of the biotechnology industry began to change, driven by finance markets that raised almost $ 4 billion dollars in the U.S. alone, and laboratory advances that have given rise to several new possibilities for the market place. A host of new pharmaceuticals are being developed as biotechnology pushes beyond its protein product base to include such things as DNA transcription blockers, anti-sense RNA molecules that inhibit protein synthesis, carbohydrate coats that smother hormone receptors, and lipids that interfere with signal transmission into cells.

In agriculture, genes for herbicide and insect resistance have been introduced into a number of agronomically important crops such as cotton, rice, potato, corn and canola; anti-sense RNA techniques are being used to inhibit ripening in tomatoes; and wheat, worth $ 60 billion annually world-wide, has recently yielded to genetic transformation techniques. Seaplants of agronomic value such as the marine algae are in the early stages of this transformation work. Highly sensitive analytical techniques for the detection and monitoring of certain marine toxins are currently ensuring the safety of the shellfish industry.

In the terrestrial and marine environments, microorganisms capable of breaking down polluting heavy oils to lighter, more manageable grades are coming onto the market, biosensors are being developed to monitor a host of trace elements and chemicals, and bacteria with a battery of easily detectable labels are being introduced as probes in environmental clean-ups.

During this same period, there were significant events in NRC's biotechnology program as it pursued its goals of research excellence in support of Canadian social-economic interests. Most notably, there was the completion of a comprehensive assessment of the sector by an external, Council-appointed review committee. This process, which included a Peer Review of the research taking place in all four sector institutes and an evaluation of the sector's effectiveness by its industry clients and other stakeholders, was generally very positive. Not only did it identify projects of international calibre, and there were many of these, but it also revealed others which needed to be redirected or modified, and in a small number of cases, terminated altogether. The assessment also called for the creation of a strategic plan for NRC biotechnology, a process that will gauge the future trends in the technology and ensure that NRC is positioned to maintain its relevance and continues to respond to national needs.

The four institute Advisory Boards completed their first full year of operation. The membership, drawn from leaders in the academic and industrial communities act as twice-yearly consultants to the institutes as they respond to the changing needs of their stakeholders.

The NRC biotechnology sector continued to strengthen the linkages between its four institutes during the year. Collaborative projects between IBS and BRI were given additional resources, local area networks were set up at each institute, a comprehensive program brochure

along with four smaller theme brochures were created, and a two-day program management meeting was held in Chantecler, Quebec aimed at stimulating inter-institute research connections. Finally, the sixth NRC Industrial Biotechnology Conference was held in Montreal in December, 1991.

The last year was a virtual watershed in terms of the biotechnology sector's expanded involvement with its external clients and other stakeholders. A total of 45 industrial interactions took place involving $ 3.5 million and upwards of 75 PYs from industry and over $ 1 million and almost 40 PYs from NRC. Some 40 collaborations occurred with universities, in which $ 1.3 million and 46 PYs from universities were matched with 20 PYs and $ 750 K from NRC. The Biotechnology Contributions program contributed upwards of $ 3 million directly to 19 collaborative partners. The sector also generated revenues, to the tune of $ 970 K for contracted services and $230 K for leased incubator lab services. Revenues generated from Biotechnology's 33 licences were just shy of $ 215 K and royalties accounted for almost $ 30 K.

Like the larger national and world enterprise then, NRC biotechnology continues to advance along the two broad, often intertwined fronts of pure research and pragmatic application. With the clearer guide into the future afforded by the strategic plan, the biotechnology sector will further consolidate and focus its resources in areas of importance to Canadian economic wellbeing.

Maurice Brossard
Vice-President, Biotechnology

2. Director General's Foreword

Dr. Warren Steck

Canada's reliance on agriculture and forestry in its economy, coupled with the rapid advances being made in biotechnologies applicable in these areas, makes plant biotechnology a vitally important part of NRC's program to promote Canadian competitiveness through research and development.

The year 1991/92 was the NRC Plant Biotechnology Institute's ninth year in operation, and a year of substantial progress on all fronts. Despite ongoing financial constraints the National Research Council continued its core support of the Institute's operations and added to our premises in Saskatoon through re-dedication of space formerly occupied by the NRC Institute for Research in Construction. Our core staff size remained unchanged but, thanks to NRC's switch from a "person-year" to "salary envelope" method of staff support, larger numbers of term staff were available within existing salary resources. The Institute also accommodated a record number of guest researchers from other organizations, made important scientific advances, and conducted a large amount of business with clients and partners. In consequence we were able to fully meet our targets for impact and leverage under the NRC Long-Range Plan.

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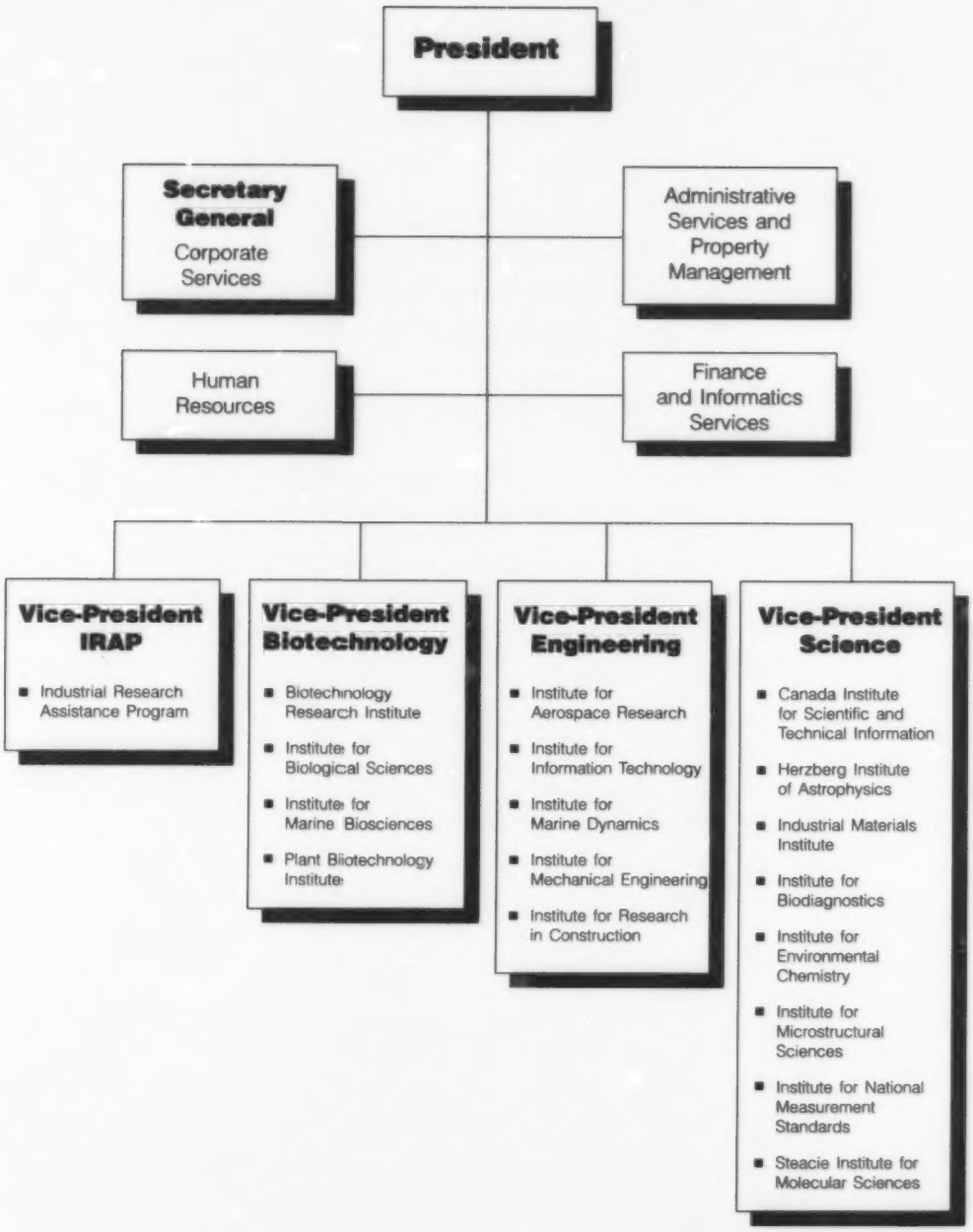
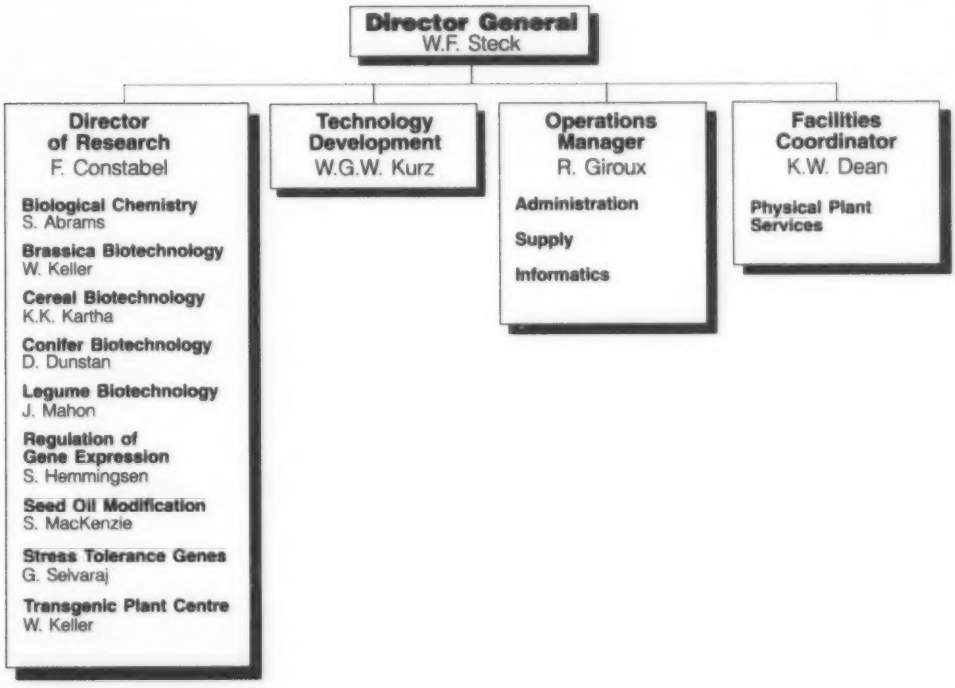


4. The Institute and its Organization

The NRC Plant Biotechnology Institute (PBI) is one of four research centres in the Council's biotechnology program, the others being the Institute for Biological Sciences in Ottawa, the Biotechnology Research Institute in Montreal and the Institute for Marine Biosciences in Halifax. PBI's part of this program is biotechnologies for application in seed plants. The diagram below shows the organization of the Institute during 1991/92.

The Organization of the NRC Plant Biotechnology Institute



5. 1991/92 Activities

5.1 Goals and Achievements

The Institute continued to focus on its designated roles as a part of NRC's overall biotechnology program. These roles call for:

- advancement of biotechnology research
- generation of new transgenic plants
- provision of facilities for industrial development
- communication with the research community
- training of biotechnology personnel

These five points remained the foundation of activities throughout 1991/92. Our activities in 1991/92 were organized into three programs: Research, Business and Outreach and Support Services.

The largest of these programs was Research, which involved 85 NRC staff and all of the guest researchers. During the year NRC restructured its "section head" management system, and the Institute brought all its research groups directly under the supervision of the Research Director — as shown in the foregoing organization chart.

Generation of transgenic technology was a fruitful theme during 1991/92. Four groups were primarily concerned with developing new methods for genetic transformation and for the regeneration of transgenic plants. Enlarging on earlier research, the transformation of alfalfa, *Brassica juncea*, *B. campestris* and wheat was newly accomplished, and genetically engineered specimens of these plants were generated and subjected to greenhouse assessments. Species previously engineered, especially canola (*Brassica napus*) and strawberry, underwent progeny testing and improvement, and as in previous years some regulated field tests were performed on advanced material.

Advancement of biotechnology also went forward in the area of DNA-based studies. Four other research groups were directed at gene isolation and identification, and at the problem of regulating gene activity in plants. New genes conferring tolerance against salinity were identified, and some previous systems' performance was improved. Effort was intensified in seed oil biosynthesis genes. Gene activation by small molecular weight biochemicals as well as by DNA sequences continued to be a focus of activity and an area of growing industrial interest. Our capabilities for study of gene effects *in vivo* were raised significantly at the end of the year through purchase of a very-high-field NMR spectrometer for this kind of work.

Facilities for industrial development *were provided at cost for projects performed by twelve Canadian firms. At the Transgenic Plant Centre the growth facilities available were enlarged and extra associated laboratory space was equipped for full-scale challenge testing of transgenic plants. Use of our facilities by industries increased by nearly 20%, and the number of corporate clients also was higher than in 1990/91. As part of the renovation project in newly-acquired building space we upgraded three laboratory units to be dedicated for industry use in 1992/93.*

The overall volume of research business in 1991/92 was larger than ever before: contracts and cash

contributions brought in almost $795 000 while the value of contributed guest labour rose to $3,720,000, for an aggregate external investment of $4.5 million on our premises. This was equivalent to 42% of NRC's own on-site investment in research at PBI during the year.

Communication with the research community was promoted through visits, joint efforts, conference attendance and the publications and newsletters of the Institute. The NRC's Advisory Board for PBI and the Peer Review carried out in 1991 provided extra dimensions to this communication process.

Training of biotechnology personnel continued at a high level throughout the year. Thirty-eight industry personnel were resident as guest researchers, and a further forty graduate students were trained on our premises towards fulfilment of their degree requirements. Twelve undergraduates from across Canada participated in the 1991 summer student program. Instructional seminars on-site drew more than two thousand attendees, and instruction by our staff at other locations benefitted a still larger number of biotechnologists.

5.2 Summary of Research Programs and Activities

Dr. Fred Constabel, Research Director

Transgenic plants of spruce and pine, wheat and barley, pea and canola are PBI's foremost goal. Such plants permit novel approaches to elucidation of plant biology and have uses in agriculture and forestry. The research program is structured to:

- demonstrate transgenic plants using reporter genes;
- isolate and characterize or acquire genes of economic interest to industry;
- express these genes at optimum levels for production of value-added plants and better crops.

Crop plants do not easily respond to manipulations required for genetic engineering. With plants targeted for engineering, embryonic cells and tissues have been identified as suitable starting material. These are used for the insertion of genes and subsequent regeneration of transformed plants. Genes have been introduced by particle bombardment into spruce, pine, wheat and pea. *Agrobacterium tumefaciens* serves as vector in pea and canola. Parameters like Agrobacterium virulence, host cell vigour, sensitivity to selection systems, and gene expression factors are under investigation in our program.

Farthest upstream of producing genetically engineered plants are experiments designed to identify gene products for future biotechnology. The generation of canola plants producing high levels of trierucin-rich oil requires the characterization of enzymes and encoding genes for elongation and desaturation of fatty acids as well as for assembly of the triacylglycerol molecule. Another goal is the identification of canola proteins which play a role in the interaction of phytotoxins, phytoalexins and virulence of *Leptosphaeria maculans*, the causal agent of blackleg disease. A third topic concerns the manipulation of hormone action, specifically germination, dormancy, drought response, and stress tolerance as effected by abscisic acid (ABA). Enzymes of ABA metabolism and the ABA receptor protein may hold the key to future manipulations.

A number of performance traits in crop plants have been obtained in the form of specific genes. These are now being inserted into plants for assessment of expression. A chitinase gene from *E. coli* which confers disease resistance is at hand as well as a betaine aldehyde dehydrogenase gene, both for expression in target plants such as canola. Genes which encode herbicide resistance have been field-tested with *Brassica napus* and are being inserted into *B. campestris*, and *B. juncea*. Experiments to achieve insect resistance by making plants the delivery system for a feeding deterrent are on-going. Tolerance to temperatures below freezing is expected in plants which carry the gene encoding antifreeze proteins.

Gene expression at optimum levels, in tissues of interest, and at the desired time of plant development without impeding prior performance and yield, will decide the market value of genetically engineered plants. At present PBI's experimentation explores the effect of regulatory sequences by using fusion genes combining selection and demarcation of transformed tissue, as well as technology referred to as promoter tagging. Post-translational processes under the control of chaperons are being elucidated in order to manipulate the assembly of functional proteins.

In a recent Review, PBI's research program was praised by peers as relevant, cohesive, and advanced, and has found wide support with industry. Growth in the molecular biology of plant development will maintain PBI's impact on agriculture and forestry in the years ahead.

5.3 Partnerships and Services

The Institute continued to participate in partnerships of five kinds.

Joint or collaborative research projects of substantial size in which resources were provided by NRC and the partners; and for which a formal Agreement was signed:

- Joint projects with companies as listed;
- Funded projects with institutions: Canola Council, Western Grains Research Foundation, Agriculture Development Fund.

Research collaborations of small size or short duration for which no formal agreement was signed:

- Work for other government scientists (Agriculture Canada, Forestry Canada, Environment Canada);
- Work with university scientists, often with Agriculture Development Fund, NSERC or MRC support.

Training of personnel by NRC staff. This was done for industrial as well as academic organizations:

- Of 136 guest researchers registering at PBI in 1991/92, an estimated 105 received training during their visits;
- Adjunct appointments allowed a further 600 students to receive some instruction from NRC scientists during the year.

Establishment of joint-access research facilities:

- Joint technical management by SEDCO and PBI of transgenic plant assessment facilities (increased 40% in 1991/92);

Guest Researchers are employees of, or sponsored by, other organizations who carry out research on the Institute's premises, usually in collaboration with NRC groups. Here, Dr. Donald Palmer, Guest Researcher from the University of Manitoba, and Michelle Cowell, PBI staff member, examine tissue cultures at the Transgenic Plant Centre.

- Joint acquisition of 500 MHz magnetic resonance instrument by University of Saskatchewan and PBI;
- Operation of joint-access electronmicroscope by University of Saskatchewan and PBI.

The Institute provided several kinds of services to external and internal clients during the year, on cost-recovery bases:

- DNA services (DNA strand synthesis, amplification and sequencing)
- Mass spectral analysis of samples
- Nuclear magnetic resonance analysis of samples
- Protein microsequencing
- Provision of laboratory and office space
- Provision of greenhouse and growth chamber space
- Consulting services

6. Management and Administration

For management, the year was challenging, opening with loss of four out of seven middle managers through NRC's Voluntary Severance Program. At about the same time the Institute underwent a rigorous set of peer, audit and client relations reviews commissioned by NRC. As a result of these events, the middle management system was re-structured and staffings began which were still not completed by year-end.

During 1991/92 NRC introduced quite a number of new programs and policies throughout the Institutes; adjustment to these absorbed a considerable amount of management time and effort. At the beginning of calendar 1992, the number of laboratory "project" groups was reduced to eight (plus the Transgenic Plant Centre) and the authority devolved on Group Leaders was increased.

Operations

Robert R. Giroux, Operations Manager

The Operations group has seen several changes during the past twelve months: the administrative staff moved into newly renovated quarters at PBI; the job of Administrative Officer was changed to Operations Manager with Mr. Robert Giroux taking up this post in mid December; and the facilities section was made a distinct group under the direction of a new Facilities Coordinator, Mr. Bill Dean. Unfortunately, at year-end the Supply Officer's chair was still vacant.

A major audit was performed on the support services at PBI last spring. The new Operations Manager has started the examination and implementation of recommendations included in the audit report. (This will continue to be an important aspect of his work load during the coming year.)

The Institute also witnessed the arrival of new computer technology in the form of an electronic network, including electronic mail capabilities with NRC staff in Ottawa. At year end, approximately 50% of the available PBI computers were fully on the network. The full network implementation at PBI will continue to be the goal for 1992/93.

A spending freeze slowed the travel activities to a standstill during the last quarter, however, this allowed our administrative staff to catch up with, and better understand the many possibilities of our new TRAX system. The human resources component was also very active with many people moving in and out of PBI.

Our supply staff performed at a high level even though the regular staff was greatly reduced by retirement, maternity and sick leave. The hiring of a Supply Officer, early in the new year, will assist in the stabilization of this section.

1992/93 will continue to supply interesting challenges such as a re-write of the Human Resources manual, stage two of TRAX, and new training and human resources policies. At the Institute, the full completion of staffing for our group, the computer network finalization and the implementation of recommendations contained in the audit report will be the primary goals in order to provide the best service possible to all PBI functions.

Facilities

K. William Dean, Facilities Coordinator

Many changes occurred during the year. Needs for major roof repairs and other renovations to facilities required the services of experienced supervisors

generously seconded from ASPM Branch in Ottawa.

Our group was reorganized from a "building maintenance" to "facilities provision". Computer services were placed with administrative services, and new leaders were hired for these groups.

Thirteen renovation projects were undertaken during 1991/92. These included the relocation of administration offices, the establishment of technology development laboratories for collaboration with outside partners, new laboratories for Cereal Biotechnology; and redevelopment of the former administrative offices into laboratory equipment rooms, offices and meeting areas. The first floor was renovated to provide new computer services rooms, maintenance shops and offices, along with an office for the facilities coordinator. The addition of the 500 MHz NMR spectrometer required significant revisions to the NMR laboratory.

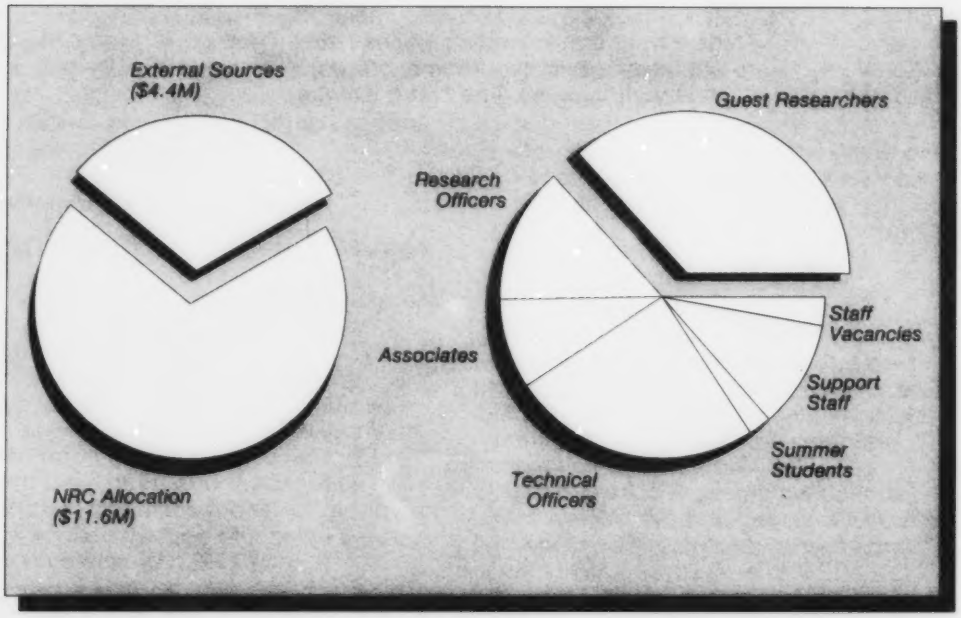
The largest single project was a $180,000 re-roofing conducted in cooperation with ASPM. The old roofing was replaced with energy saving insulation and improved moisture protection. The original main building and the south wing received new roofs.

Two new growth chambers were added to inventory. One unit was installed in the Transgenic Plant Centre and one unit at the Gymnasium Road Building.

7. Resource Profile

Resource use at PBI in 1991/92

An estimated $16.0 million was expended at PBI during the year, and labour input was equivalent to 172 person years. Of these totals, NRC's share was $11.6 million supporting its 84 continuing and 23 limited-term staff, while other organizations invested $4.4 million and sponsored the equivalent of 65 full-time research personnel working alongside the Council's own staff in our laboratories. The pie graphs below show the overall financial and human resources picture of the Institute for the year.



NRC's expenditures of $11.6 million were at the same level as the three previous years, and reflect spending power erosion of nearly 15% since 1988/89. More than half of this investment was expended on staff salaries. All operational expenses of the Institute accounted for one-third of the total and the remainder went for capital items of which the largest ($0.6M) was a shared-cost new biological NMR facility. The two graphs below detail these expenditures.

Of the estimated $4.4 million in non-NRC investment, $0.12 million was obtained as fees for client services; $0.3 million was received for joint research; $0.11 million was for shared acquisition of equipment; and the $3.9 million balance was as salary support of guests in the laboratories. In 1990/91 the external investment level at PBI was $4.2 million, and in 1989/90 just $2.8 million.

8. Advisory Board

The PBI Advisory Board consists of knowledgeable members of the plant biotech community appointed by NRC and advising the Council itself. During 1991/92 the Board met twice.

CHAIRMAN : Dr. Wallace Beversdorf, Crop Science Department, University of Guelph (Guelph, Ontario)

Dr Guy Bellemare, Professeur titulaire, Faculté des sciences, Laval University (Sainte-Foy, Quebec)

Mr John Cross, President, Philom Bios Inc. (Saskatoon, Saskatchewan)[NRC Council member]

Dr Ian De La Roche, President and CEO, Forintek Inc. (Vancouver, British Columbia)

Dr André Fortin, Directeur-général, Institut de recherche en biologie végétale,Université de Montréal (Montréal, Québec)

Dr Jeremy Gawen, Miller Dallas (Toronto, Ontario)

Dr Gordon Maclachlan, Biology Department, McGill University (Montreal, Quebec)

Dr Jagmohan Maini, Assistant Deputy Minister, Forestry Canada (Hull, Quebec)

Dr Jack Manns, Associate Vice-President (Research), University of Saskatchewan (Saskatoon, Saskatchewan)

Dr Trevor Thorpe, Associate Dean of Research, University of Calgary (Calgary, Alberta)

Mr Robert Virgo, Director of Corporate Development, Saskatchewan Wheat Pool (Regina, Saskatchewan)

EX-OFFICIO : Dr Maurice Brossard, NRC Vice-President (Biotechnology) (Montreal, Quebec)

EX-OFFICIO : Dr Warren Steck, Director General, NRC Plant Biotechnology Institute (Saskatoon, Saskatchewan)

SECRETARY : Dr Paul Matteau, Director, NRC Biotechnology Program Office (Montreal, Quebec)

9. Research Activities

The following pages detail the research activities of each research group during 1991/92. The Research Groups are depicted in PBI's Organization Chart on page 3.

9.1 Biological Chemistry Group

Research Officers:
Suzanne R. Abrams (Leader), John J. Balsevich
Technical Officers:
Gregory Bishop, Angela Shaw, Laurie Friesen (Feb-Mar 1992)
Research Associates:
Patricia Rose, Michel Perras (from Oct 1991)

Guest Researchers:
Garth Abrams, Larry Gusta, Nancy Lamb, Bo Lei, Dennis Barton, Xiang Yin
Summer Students:
Suzanne Jacques, Ebba Kurz

Our goals are to understand how the plant hormone abscisic acid (ABA) acts in regulating diverse aspects of plant growth including seed development, germination and transpiration. We are developing ABA-like chemicals for improving plant performance, e.g. better seed germination and tolerance to environmental stress. We are working towards identifying bio-molecules involved in ABA perception by plants – receptors, binding proteins and carrier molecules.

Research in 1991/92

A new generation of optically active ABA analogs has been developed as probes to relate physiological effects with expression of subsets of ABA-inducible genes. One array (fig.) was synthesized and used to examine the structural requirements of the ABA recognition response in wheat dormant seed embryos. The ABA analogs that inhibited embryo germination exhibited differential effects on ABA-responsive gene expression. All active analogs induced two ABA-responsive genes, wheat group 3 *lea* and *dhn* (*rab*), while two compounds that were potent inhibitors of germination were much less effective in inducing the ABA-responsive *Em* gene, suggesting that the latter gene is not involved in germination inhibition. A mass spectrometric method for direct detection and quantitation of ABA and sugar conjugates has been developed. Components of plant extracts are separated by HPLC with fused silica capillary column coupled to the mass spectrometer, ionized by continuous flow fast atom bombardment, and analyzed by observing both the molecular ion and ABA fragments (multiple reaction monitoring).

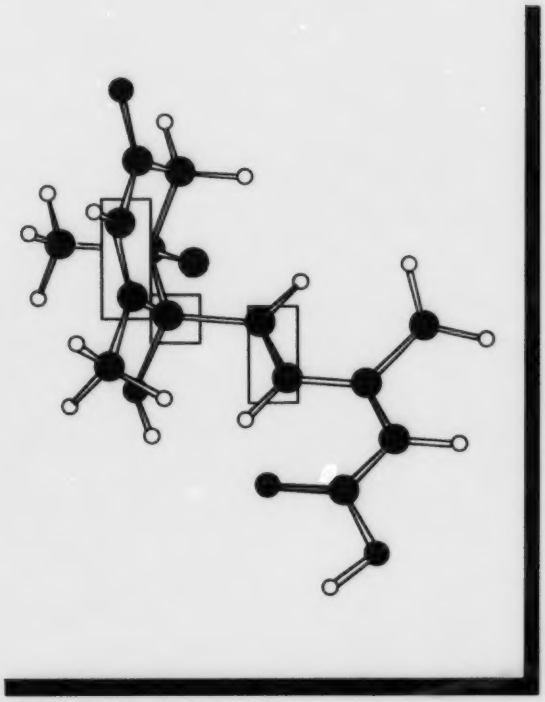


Figure 1. Design of Abscisic Acid analogs. Rectangles and gram atoms denote alteration of the ABA molecule.

Partnerships in 1991/92

Collaborations have continued with industrial, academic and government partners on ABA projects, including NRC/university/industry collaborations sponsored by Prairie Malt Ltd (malting barley) and Pioneer HiBred/UGG (canola). Studies have been carried out with USDA scientists K. Walker-Simmons (wheat) and J. Suttle (cotton), and research groups at various universities including: Saskatchewan (L.V. Gusta, M. Devine, K. Tanino), Manitoba (R.D. Hill), Calgary (M. Moloney), North Carolina (R. Quatrano), New South Wales (B.V. Milborrow), and Victoria (N. Livingston).

Spectroscopic Services

Research Associate:
Edward Kendall (from Oct. 1991)
Technical Officers:
Brock Chatson, Lawrence Hogge, Doug Olson

The NMR Laboratory, equipped with a Bruker AM-360-WB instrument provided PBI project scientists and clients with analyses of 1H, 13C, and 31P. In 1991/92 a 500 MHz instrument was acquired in partnership with the University of Saskatchewan. As well, microimaging and solids accessories were obtained for the AM-360-WB instrument for *in vivo* BioNMR experiments. With two mass spectrometers, a Finnigan 4500 and VG 70-250 SEQ, the PBI Mass Spectrometry Laboratory provided high resolution exact mass, low resolution GC/MS, LC/MS, and MS/MS analyses for PBI scientists and outside clients.

9.2 Brassica Biotechnology Group

Research Officers:
Wilf Keller (Leader), Jan GrootWassink, Janet Taylor
Technical Officers:
Carla Barber, Joe Hammerlindl, Allan Kolenovsky, Janice Schmidt, Marvin Swartz
Research Associates:
Alison Baillie, Mohamed Eweida, Victor Morales
Guest Researchers:
Vivijan Babic, Brigitte Bauer-Weston, Jim Cunningham, Raju Datla, Nabil El-Rouby, Cathy Kuiack, Sun Lee, Karen Oddie, Soledade Pedras, Connie Sauder, Ole Thangstad

The objectives of this group include the development of enabling technology for Brassica crop improvement focused on microspore embryogenesis, gene transfer, glucosinolate alteration, and manipulation of fungal disease resistance.

Research in 1991/92

Gene transfer methodology
In collaboration with Hoechst Canada researchers, modified gene constructs were employed to generate more than 20 new transgenic lines of *Brassica napus* with resistance to the herbicide, Ignite. Several of these lines possessed enhanced tolerance to the herbicide in contrast to lines previously generated.

More than 40 transgenic *B. napus* lines were obtained in experiments involving the introduction of a gene for pyruvate kinase (PK), a glycolytic enzyme catalyzing the initial step of the metabolic pathway for fatty acid biosynthesis. The aim of this research is to enhance oil content of canola seeds by over-expressing the PK gene. Seed obtained from 18 homozygous transgenic lines will be used for field

trials in 1992. This collaborative project with Queen's University and Agriculture Canada is partially supported by a NSERC strategic grant.

Microspore culture methodology
A microspore culture protocol for *Brassica campestris* was improved to the extent that embryogenesis and haploid plant regeneration could be achieved in twelve cultivars. A procedure for chromosome doubling was optimized and more than 100 diplodized lines were regenerated and self pollinated to produce homozygous seed for field assessment. This cooperative project with Agriculture Canada is supported by a grant from the Canola Council of Canada.

Fungal disease resistance
Molecular and chemical techniques were employed to develop a protocol which facilitated the identification of virulent isolates of *Leptosphaeria maculans* the causal organism of blackleg. Research was initiated to identify fungal genes associated with virulence and to identify genes in *Brassica juncea* which confer resistance to blackleg. A simple and rapid method for detecting seed contaminated with blackleg inoculum was also developed. Research on fungal pathogens has continued to be carried out in cooperation with Agriculture Canada researchers.

Alteration of glucosinolate content
A project on the isolation and manipulation of the gene(s) coding for myrosinase was initiated in May, 1991. The aim of this research is to over-express myrosinase activity in the vascular tissue of Brassica ssp. in order to degrade glucosinolates during translocation and thereby retard their accumulation in developing seeds. Based on the amino acid sequence of myrosinase from *Sinapis alba* (made available through collaboration with Trondheim University), probes were constructed for screening a *B. napus* cDNA library. Several putative clones were isolated and some of these cross-reacted with a partial cDNA myrosinase clone of *Arabidopsis thaliana* (provided through cooperation with the University of Washington). Experiments to isolate and characterize full length clones are in progress.

Partnerships in 1991/92

A three-year contractual agreement with Hoechst Canada involving the application of gene transfer technology to develop herbicide resistant Brassica crops entered its second year. Hoechst currently has a team of six researchers collaborating with PBI's staff.

An IRAP-M project with ICI Seeds Canada involving the application of microspore technology in the company's *B. napus* breeding program entered its second year and will be completed by December, 1992. Methodology for reliable production of haploids was transferred to ICI.

A project supported by the NRC Biotechnology Contribution Fund (BCF) and based on the application of microspore technology to *B. juncea* breeding was initiated in September, 1991 in collaboration with the Saskatchewan Wheat Pool. This three-year undertaking involves the employment of two Wheat Pool researchers in NRC facilities under the guidance of PBI staff.

A three-year proposal aimed at enhancing disease resistance and insect tolerance through the transfer of foreign genes into canola has received BCF support. The industrial partner for this project incudes the Canola Council of Canada in association with the Saskatchewan Canola Development Commission. The research will be undertaken at PBI by a scientist and technician employed by the Canola Council.

9.3 Cereal Biotechnology Group

Research Officers:
Kutty K. Kartha (Leader), Ravindra Chibbar, Kuo-Nan Kao
Technical Officers:
Karen Caswell, David Horn, Nick Leung, Morris Michayluk, Keith Pahl, Lee Steinhauer
Research Associates:
Monica Baga and Narender Nehra
Guest Researchers:
Darryl Arsenault, Rahim Honarnejad, Grace Johnson, Debbie Lashta, Linda McGregor, Y. Niu, Brian Orshinsky, Brian Weir, Ming Ye

The research goal of this group is to develop enabling technologies for the genetic engineering of wheat and barley for incorporation of novel agronomically useful genes in order to enhance the socio-economic benefits for Canada.

Research in 1991/92

Genetic engineering of wheat and barley:
During 1991-92, we developed a genotype-independent enhanced regeneration system for both wheat and barley by judicious manipulation of tissue culture components and immature zygotic embryo-based explant sources. We obtained regeneration frequencies in the range of 80-90% with an average of 10-15 somatic embryos per explant within 3-4 weeks of *in vitro* culture. To enhance the expression of genes introduced into the systems via microprojectile bombardment we used a regulatory region of rice actin gene along with its first intron. This gave maximal expression of the *gus* gene. Wheat embryogenic calli expressing the *gus* gene were regenerated into plants. Molecular screening of transformants revealed that the *gus* gene was expressed in the leaves. The detection of the *gus* fragment in the genomic DNA of these leaves also proved that the introduced genes have been integrated into the host genome. Selection strategies using various selective agents are being developed in order to increase the transformation efficiency. Promoters for targeting genes into seeds and somatic embryos of wheat are now being identified.

Anther and microspore culture of barley
Microspores being single haploid entities are ideal gene recipient systems. In order to develop a microspore culture system for barley, several factors were evaluated for the stabilization and induction of cell division. Although sugars were essential for sustained cell division, most of the sugars we examined, including maltose, were destabilizing agents. With the stabilizer polyethylene glycol in combination with ficoll, 12% of the cultured microspores underwent sustained cell division leading to the formation of microcalli. In anther culture research, over 100 homozygous diploid barley plants were produced from a hybrid for the production of new cultivars with resistance to barley rust disease. The seeds of these plants were handed over to the Saskatchewan Crop Development Centre for further evaluation.

Partnerships in 1991/92

The Saskatchewan Wheat Pool continued to be a major collaborator even after the completion of an IRAP-funded project. Currently the Pool collaborates with us on using the haploidy system developed under the IRAP program for the genetic engineering of wheat.

The Western Grain Research Foundation's partnership continues through a research grant of $35,000/year for 3 years for enhancing our efforts on the genetic engineering of wheat and barley. Similarly with a major multinational biotechnology company, a strategic alliance was agreed upon for cost-shared collaborative research for the improvement of wheat through genetic engineering.

Other collaborators of the Group include Saskatchewan Crop Development Centre, Agriculture Canada, and the Universities of Saskatchewan, Alberta, Western Ontario, Victoria, and Florida.

9.4 Conifer Biotechnology Group

Research Officers:
David Dunstan (Leader), Martin Lapp, Edward Tsang
Technical Officers:
Terry Bethune, Cheryl Bock, Maxine Coffey, Janet Condie
Research Associates:
Venkat Bommineni, Jin-Zhuo Dong, Gilles Pilate
Guest Researchers:
Robin Browne, Shufen Hou, Susan Kikcio, Monika Luisdorf, Maria Moore, Yi-Cong Niu, Tom Tautorus

The aim of the Group is to develop and apply biotechnology to conifer trees. Particularly the development of procedures for the production and multiplication of genetically improved material.

Black spruce seedling derived from somatic embryogenesis.

Research in 1991/92

We have obtained shoots from buds of 1 to 5-year-old *Pinus monticola* trees cultured *in vitro*. There is an interaction between medium composition, benzyladenine concentration, time of explantation and tree age. Efforts are now directed toward improving shoot induction and elongation. Hedging and hormonal spray treatments *in vivo* have influenced the development of procedures for improved rooting of cuttings from 1 to 10-year-old trees of *Pinus banksiana*.

In our research with suspension cultures of somatic embryos of *Picea glauca* we have investigated the use of phytohormonal pre-treatments, prior to use of racemic abscisic acid to obtain embryo maturation. Our results have shown that such treatments affect subsequent abscisate metabolism and influence embryo maturation, indicating that they have potential in the

stabilization of maturation response in long-term suspension cultures. We have also characterized effects of racemic phaseic acid and dihydroabscisic acid on somatic embryo maturation. Neither compound evokes an equivalent response to racemic ABA. This research involves internal collaboration with Dr. Suzanne Abrams.

Our work with electroporation was directed toward obtaining stable transformation. The conditions for electroporation and for protoplast culture, have been re-evaluated to ensure the maximum survival of cultures after electroporation. Research focused on the use of enriched media for the culture of protoplasts in low density, and on recovery of embryogenic cultures after electroporation with plasmid DNA. The detection of foreign genes in transformants is the focus of current research. Experiments with the microprojectile technique have been directed toward characterization of transient expression using various DNA constructs. We have examined the enzyme cinnamyl alcohol dehydrogenase, including method development for protein isolation and standardization of enzyme assay.

Partnerships in 1991/92

Our major partner this year was B.C. Research Corporation's Forest Biotechnology Centre, continuing a three-year collaboration (valued at $2.5 million) toward the development of commercially useful procedures in somatic embryogenesis for "plant cloning". We have worked also with Weyerhaeuser Canada, Forestry Canada (Pacific Forestry Centre and Petawawa National Forestry Institute), and the Universities of Calgary and Saskatchewan.

9.5 Legume Biotechnology Group

Research Officers:
John Mahon (Leader), Shaun Hobbs, Louise Nelson
Technical Officers:
Maureen Anderson, David Baliski, Catherine DeLong, Connie Knapp
Research Associates:
Mark Jordan, Hans Rempel
Guest Researchers:
David Feindel, Sue Grayston, Colin Kindrachuk, Jiyue Liu, Isabelle Poisson, Om Rajora
Summer Students:
Rowena Chow, Richard Weger

The objective of this project is to promote the genetic improvement of Canadian legume crops through biotechnology. Research in 1991/92 attacked the major problem - poor production and recovery of genetically engineered plants.

Research in 1991/92

The existing transgenic pea plants were used to study the relationship between T-DNA structure and gene expression in pea and to initiate work on optimizing selection methods. No new transgenic peas were recovered, but *Agrobacterium* vectors were developed with superior transformation ability in both the cotyledonary nodes and embryo axes used for plant regeneration. Delivery of *Agrobacterium* and genes for selection have also been improved and work on the transfer of genes into pea tissues by particle acceleration has increased with the addition of PBI's second Biolistics apparatus.

The method for producing multiple *de novo* pea plants has been adapted for use with bean, lentil and chickpea, and an embryogenic system has been developed for the regeneration of

alfalfa plants from cell suspension cultures.

Agrobacterium-mediated transformation of plant cells in suspension culture is now possible and has identified significant effects on transformation of both the Ti plasmid construction and the physiological state of the plant cells. It has also shown that tobacco cells can induce *Agrobacterium* vir genes, but that no such induction occurs with pea cells, unless acetosyringone is also added.

Dr. Shaun Hobbs completed his gene expression work, showing that even transient expression of genes is repressed in poorly expressing transgenic plants. He also showed control of reporter gene expression by the 5'- fragment from the pea lipoxygenase gene, he isolated.

Partnerships in 1991/92

The project completed the ADF-funded project on molecular markers for lentil, but continues to work on the Rhizobium assessment project. A MicroBio Rhizogen contract has been extended.

DNA Services Unit Staff

Larry Pelcher, Don Schwab, Barry Panchuk

This unit continued to increase and improve its services to all PBI's research projects, and outside clients. In 1991/92, the addition of a new DNA/RNA synthesizer helped to increase oligonucleotide synthesis to 910. Over 700,000 bases of DNA sequence were determined and new purification, PCR applications and labelled oligonucleotides are now being provided.

Third generation transgenic peas being tested at PBI's Transgenic Plant Centre for inheritance of foreign genes.

9.6 Regulation of Gene Expression Group

Research Officers:
Sean Hemmingsen (Leader), William Crosby, Raju Datla
Technical Officers:
Diana Bekkaoui, Jacek Nowak, Peter Schorr
Research Associates:
Faouzi Bekkaoui, Lynn Cloney, Huacheng Wu
Guest Researchers:
Roberto Bacchetto, Dr. Mohan Balasubramanian, Diana Collins, Dr. Larry Holbrook, Mondee Redmen

Background

To successfully apply recombinant DNA technology for crop plant improvement it is necessary to:
(1) identify genes with the potential to affect a valuable trait, (2) provide the appropriate regulatory sequences which will direct the transcription of that gene in the appropriate tissues and at the appropriate time in the target plant, (3) ensure that the gene product will be synthesized, targeted to the appropriate location in the cell and correctly folded and assembled into a functional structure. Each of these areas represents a strategically critical area requiring both basic and applied research for plant biotechnology to progress.

General Objectives

The research carried out by the Gene Expression Group continues to address each of the three objectives described above. Each of the individual laboratories is engaged in research to identify valuable genes. In addition, the Hemmingsen laboratory has focused on the problem of controlling protein folding and assembly and the Crosby and Datla laboratories have focused on regulatory sequences. Molecular genetic expertise continues to be provided to other PBI projects.

Research Highlights 1991/92

Chaperonins We have continued to characterize the chaperonin genes and proteins of *B. napus* and *A. thaliana*. These proteins have been implicated in the folding and assembly of the subunits of rubisco, a key enzyme controlling plant productivity. We have begun to characterize the unexpected number of diverse chaperonin genes and proteins present in the plant. To this end we have developed a method for assessing the functions of the genes and proteins using the bacterium *E. coli* as a surrogate genetic system.

Regulatory sequences We have identified and characterized a number of novel regulatory sequences using our previously developed GUS-NPT fusion gene for random-insertion tagging.

Acetolactate synthase Field testing is in progress of herbicide resistant *B. napus* in collaboration with Agriculture Canada and the University of Calgary. We have continued to investigate the biochemistry of this important target enzyme.

An important premise for the directed genetic alteration of plants is the ability to express modified genes at a specific time or place during development, and to understand the underlying mechanisms by which such regulation of gene expression is achieved. Accordingly, the group has pursued the identification of numerous plant gene regulatory sequences which are associated with genes that are expressed at specific points in development. Some of these regulatory sequences have been recovered and, in combination with foreign genes,

shown to express the new gene combination in a specific target tissue.

The recovery of an array of different developmental gene-regulatory sequences has enabled the development of novel approaches to modifying the biochemistry, metabolism or anatomical structure of plants. It also permits the production of pharmaceutically important peptides, the accumulation of useful intermediates in cell metabolism, or the elimination of undesirable secondary metabolites. The development of fundamental technologies leading to these objectives is becoming an important component of the group's activities.

View of one of the laboratories in the Seed Oil Modification group. Back, left to right: Darwin Reed, Dr. David Taylor, Michael Giblin; Front, left to right, John Magus, Don Tenaschuk.

9.7 Seed Oil Modification Group

Research Officers:
Samuel L. MacKenzie (Leader), Ljerka Kunst, David C. Taylor, L. Holbrook (term)
Technical Officers:
Michael Giblin, John R. Magus, Darwin Reed, Don Tenaschuk, Dennis Barton (term), Eric Pass (term)
Research Associates:
Resham Bhella (From Dec. 1991)
Guest Researchers:
M. Devine, G. Haughn, C. Ntiamoah

Our goal is to transform *Brassica napus* L. to produce seed oils rich in very long chain fatty acids (eicosenoic and erucic) having industrially desirable properties. Work focused on two elements in the biosynthetic pathway and on the development of plant transformation technology:

- the elongases producing very long chain fatty acids;
- the enzymology of triglyceride assembly;
- *in planta* transformation of *Arabidopsis thaliana*.

Research in 1991/92

Understanding the process of very long chain fatty acid synthesis is central to generating an increased supply for deposition in triglycerides. Genetic studies of *A. thaliana* mutant lines deficient in fatty acid elongation showed that elongation from C18:1 to C20:1 depends on at least three different enzymes and is controlled by a single nuclear gene designated FAE1. High resolution mapping of this gene has been completed and its position on the *A. thaliana* genetic map, with respect to restriction

fragment length polymorphisms, has been determined. The nearest RFLP marker was used to initiate chromosome walking and three positive clones have been isolated from yeast artificial chromosome libraries.

Erucic acid is not inserted into the middle position of triglycerides in *B. napus* seed oils. Therefore, *Limnanthes douglasii* was targeted as the source of a gene to transform *B. napus* to overcome this barrier. Excellent progress has been made in "solubilizing" and stabilizing the protein from a number of oilseed sources, including meadowfoam, rapeseed and safflower. A safflower gene expression library has been generated in preparation for screening to obtain the gene sequence.

We have demonstrated, for the first time, that both zygotic and microspore-derived embryos of *B. napus* incorporate very long chain fatty acids into triglycerides via the Kennedy Pathway in a concerted mechanism intimately linked to their biosynthesis by elongases.

A novel *in planta* transformation method for *A. thaliana* was tested successfully. Simple, fast *in planta* transformation will be a valuable tool for generating transgenic plants, because it circumvents problems associated with tissue culture techniques.

Partnerships in 1991/92

Some research was conducted in collaboration with Dr Pomeroy (Agriculture Canada), Drs Mukherjee and Weber (German Federal Centre for Lipid Research), Drs Somerville and Ohlrogge (Michigan State University), and several other university groups in the United States and Canada.

9.8 Stress Tolerance Genes Group

Research Officers:
Gopalan Selvaraj (Leader), Adrian Cutler, Fawzy Georges
Research Associates:
Luc Adam
Technical Officers:
Rozina Hirji, Eugen Kurylo, Mary Loewen, Bob Papish, Sandra Polvi
Guest Researchers:
Ravi Jain, Adrienne Woytowich, Mikyung Chung, Armel Gallet, Michael Thompson, Peter Shargool, Mohammed Saleem, Hong Wang, Susan Scutchings, Raman Kapur, Meiqin Qi, Atta Hussain

The goals of this group are to identify and define genes and gene products which contribute to adaptation and tolerance to environmental stress. Intertwined with these are the objectives to manipulate heterologous genes of potential adaptive value, for optimal expression and regulation in plants. These genes include osmolyte biosynthesis genes of bacteria and plants (relevant to salinity and drought tolerance), winter flounder antifreeze genes (for manipulation of frost tolerance) and genes concerned with ammonia disposal under stress conditions.

Research Highlights of 1991/92

Accumulation of glycinebetaine (betaine) by some plants is considered an adaptive strategy against osmotic stress caused by salinity or drought. Unlike some bacterial systems where there is a formal proof for this role of betaine, there is very little genetic insights into this phenomenon in plants. We are attempting to manipulate betaine synthesis in plants, employing the genes and coding sequences we had isolated earlier. Transgenic tobacco plants (model

systems) containing a bacterial and a plant coding sequence for betaine aldehyde dehydrogenase (BADH) were obtained. While the plant coding sequence from a halophyte (*Kochia scoparia*) is expressed in tobacco, the *Escherichia coli* BADH is not. In concurrent efforts, we have identified a number of messenger RNA populations that are induced in *Kochia scoparia* subjected to salinity stress, and cDNA clones for these mRNA have been isolated. Efforts to isolate the corresponding promoter elements, which will be used in conjunction with the osmolyte biosynthesis genes, are underway.

The winter flounder antifreeze protein (AFP) has a number of potentially beneficial properties with respect to improving plant cold hardiness. The most important are its ability to lower the freezing temperature and reduce the rate and extent of ice crystal growth once freezing has started.

A number of problems have been overcome with respect to detection of the AFP in transgenic plant tissue and the design of the vectors incorporating the AFP sequence. A novel extraction/purification scheme was developed for detecting AFP in transgenic plants. This method is being used to screen lines of transgenic tobacco. Various transformation vectors have been employed. The new vectors are small (5.5 kb) and incorporate both a yeast and bacterial origin of replication. In the new sequence environment, the AFP gene does not accumulate the mutations and deletions previously observed.

An important objective of the research is to couple the AFP coding sequence with regulatory sequences that facilitate high level expression during times of frost risk. Accordingly, promoter sequences that preferentially drive expression of plant genes at low temperature have been cloned and sequenced.

We are also working toward obtaining additional genes that have potential for improving plant cold hardiness. Genomic clones containing genes induced by low temperature in various *Solanaceae* have been obtained and a protein from snow mould fungi with antifreeze-like properties (psychromorbidin) has been partially characterized. Psychromorbidin has been detected in *Coprinus psychromorbidus, Typhula incarnata* and *Myriosclerotinia borealis* growing at 4°C. Its synthesis is induced in *C. psychromorbidus* by lowering the temperature from 10°C to 4°C.

Partnerships in 1991/92

The work involved participation by guest researchers from the University of Saskatchewan and University of Calgary. Part of the AFP work described above was supported by a grant from the Saskatchewan Agriculture Development fund. Some of the experiments with transgenic AFP-expressing plants were done in collaboration with Dr John C. Sanford and colleagues at Cornell University.

9.9 Transgenic Plant Centre Group

Research Officer:
Wilf Keller (Head of the Centre)
Technical Manager:
Jerry Shyluk
Technical Officers:
Michelle Cowell, Don Dymond, Gina Feist
Guest Researchers:
Perry Aulie, Colleen Bennett, Blaine Chartrand, Keith Coldwell, Delwin Epp, Jarret Gatzke, Laverne Goodsman, Colin Kindrachuk, Mary Leggett, Charlene McArthur, Elizabeth Prusinkiewicz, Michael Oelck, Angie Salter, Christine Stewart, Cherylynn Walters, Hung-Mei Wang, Jia Xie, Brent Zettl, Zui-mei Zhang

The Transgenic Plant Centre is a specialized facility for propagation and testing of transgenic plants. It is situated in the Kristjanson Biotechnology Complex owned by the Saskatchewan Economic Development Corporation and located in Innovation Place, 2 km north of the National Research Council building. The Centre comprises 550 square meters of "transgenic"-specification greenhouses and 350 square metres of associated laboratory/office space.

By March 1992, the Centre reached 100% occupancy and housed more than 60,000 plants including transgenic lines of strawberry, pea and canola. During the year, additional tissue culture incubators and plant growth chambers were installed for regeneration of new transgenic lines. Three chambers have been serviced with filtered exhaust systems to permit challenging of transgenic plants with insect pests and fungal pathogens without risking escape of inoculum into the environment. Equipment which can be used to thresh single plants was acquired for common use by PBI and its partner organizations. A computerized inventory for filing information on seeds of transgenic lines was developed. Secure cabinets for short term storage of transgenic seed were also installed.

The Transgenic Plant Centre serves as a clearing house for transgenic lines being advanced to field trials. During 1991/92 transgenic *B. napus* lines produced by the insertion of modified pyruvate kinase and acetolactate synthase genes were propagated in the Centre to produce several grams of homozygous seed of each line. Applications requesting permission to undertake field trials during the summer of 1992 were submitted to the Plant Products Division of Agriculture Canada.

The Centre houses PBI personnel engaged in Brassica microspore culture research, however, most of the space is used by private sector organizations. This has contributed to significant research advances made by PBI's industrial partners during 1991/92. The major partner companies included Hoechst Canada Inc., Philom Bios Inc., Micro Bio Rhizogen, Prairie Plant Systems and the Saskatchewan Wheat Pool. The Centre received visits from more than 50 Canadian and 40 foreign organizations during the year. A number of group tours were also conducted including a visit by more than 200 delegates participating in the Eighth International Rapeseed Congress in July 1991.

Annex I: 1991 Publications

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Rozwadowski, K.L., G.G. Khachatourians and G. Selvaraj. 1991. *Choline oxidase, a catabolic enzyme in* Arthrobacter pascens*, facilitates adaptation to osmotic stress in* Escherichia coli*. Journal of Bacteriology, 173: 472-478. NRCC No. 32463.*

Selvaraj, G. 1991. *Stress tolerance gene project: a review of activities and progress 1986-1990. NRC Internal Report PBI-91-08, 54 + v pages.*

Simmonds, D.H., N.E. Long and W.A. Keller. 1991. *High plating efficiency and plant regeneration frequency in low density protoplast cultures derived from an embryogenic* Brassica napus *cell suspension. Plant Cell Tissue and Organ Culture 27: 231-241.*

Sharma, S., F. Georges, R.E. Clevit, L.T.J. Delbaere, J.S. Lee and E.B. Waygood. 1991. *Epitope mapping by mutagenesis distinguishes between the two tertiary structures of the histidine-containing protein, HPr. Proceedings of the National Academy of Science, New York, 188: 4877-4881.*

Shelp, B.J., D.C. Taylor and L.M. Nelson. 1991. *Carbon and nitrogen partitioning in young nodulated pea (wild type and nitrate-reductase-deficient mutant) plants exposed to NO_3- or NH_4+. Canadian Journal of Botany 69: 1780-1786.*

Songstad, D.D., W.G.W. Kurz and C.L. Nessler. 1991. *Tryptamine accumulation in* Nicotiana tabacum *transformed with a chimeric tryptophan decarboxylase gene. Phytochemistry 30: 3245-3246. NRCC No. 32459.*

Sproule, A., P. Donaldson, M. Dijak, E. Bevis, R. Pandeya, W.A. Keller and S. Gleddie. 1991. *Fertile somatic hybrids between transgenic* Nicotiana tabacum *and transgenic* N. debneyi *selected by dual antibiotic resistance. Theoretical and Applied Genetics 82: 450-456.*

Steck, W. 1991. *Biotechnology & the environment in 1990. In: "Canadian Environmental Directory 1991", A.M. Aldighieri (Editor), pp 11-14. Canadian Almanac & Directory Publishing Company, Toronto.*

Tallevi, S.G. and W.G.W. Kurz. 1991. *Detection of ginkgolides by thin-layer chromatography. Journal of Natural Products 54: 624-625. NRCC No. 32472.*

Takahata, Y. and W.A. Keller. 1991. *High frequency embryogenesis and plant regeneration in isolated microspore cultures of* Brassica oleracea*. Plant Science 74: 235-242.*

Tautorus, T.E., L.C. Fowke and D.I. Dunstan. 1991. *Somatic embryogenesis in conifers. Canadian Journal of Botany 69: 1873-1899.*

Taylor, D.C., N. Weber, D.L. Barton, E.W. Underhill, L.R. Hogge, R.J. Weselake and M.K. Pomeroy. 1991. *Triacylglycerol bioassembly in microspore-derived embryos of* Brassica napus *L. cv Reston. Plant Physiology 97: 65-79. NRCC No. 32473.*

Taylor, D.C. 1991. *Seed oil modification workshop: A Synopsis. PBI Bulletin, The NRC Plant Biotechnology Institute, (January, 1991) pp. 4-5.*

Taylor, J.L., I.E. Borgmann and G. Séguin-Swartz. 1991. *Electrophoretic karyotyping of* Leptosphaeria maculans *differentiates highly virulent from weakly virulent isolates. Current Genetics 19: 273-277. NRCC No. 32467*

Tsang, E.W.T., C. Bowler, D. Herouart, W. Van Camp, R. Villarroel, C. Genetello, M. Van Montagu and D. Inzé. 1991. *Differential regulation of superoxide dismutases in plants exposed to environmental stress. The Plant Cell 3: 783-792.*

Walker-Simmons, M.K. and S.R. Abrams. 1991. *Abscisic Acid Physiology and Biochemistry: Use of ABA immunoassays. In: Environmental Plant Biology. pp 53-61.*

Walker-Simmons, M.K., M.J.T. Reaney, S.A. Quarrie, P. Perata, P. Vernieri and S.R. Abrams. 1991. *Monoclonal antibody recognition of abscisic acid analogs. Plant Physiology 95: 46-51.*

Wang, H., A.J. Cutler and L.C. Fowke. 1991. *DNA replication and the development of preprophase bands in soybean protoplast cultures. Physiologia Plantarum 82: 150-156. NRCC No. 32474.*

Wang, H., M. Saleem, L.C. Fowke, and A.J. Cutler. 1991. *DNA synthesis in maize mesophyll protoplasts in relation to source tissue differentiation. Journal of Plant Physiology 138: 200-203. NRCC No. 30914.*

Wang, H., G.P. Slater, L.C. Fowke, M. Saleem and A.J. Cutler. 1991. *Comparison of cell wall regeneration on maize protoplasts isolated from leaf tissue and suspension cultured cells. In Vitro 27: 70-76. NRCC No. 32458.*

Wang, H., A.J. Cutler and L.C. Fowke. 1991. *Microtubule organization in cultured soybean and black spruce cells: interphase-mitosis transition and spindle morphology. Protoplasma 162: 46-54.*

Weselake, R., D.C. Taylor, E.W. Underhill and M.K. Pomeroy. 1991. *Properties of diacylglycerol acyltransferase from microspore-derived embryos of* Brassica napus. *Phytochemistry 30: 3533-3538. NRCC No. 32479.*

Xiao, W., L.E. Pelcher and G.H. Rank. 1991. *DNA sequence divergence and functional conversation at the* STB *locus of yeast 2 m circle variants. Bacteriology 173: 1181-1186.*

Xiao, W., L.E. Pelcher and G.H. Rank. 1991. *Sequence diversity of yeast 2 m* RAF *gene and its coevolution with* STB *and* REP1. *Gene 1: 75-80.*

Xiao, W., L.E. Pelcher and G.H. Rank. 1991. *Evidence for cis- and trans-acting element coevolution of the 2 m circle genome in* Saccharomyces cerevisiae. *Journal of Molecular Evolution 32: 145-152.*

Annex II: Awards and Distinctions

Dr. Kutty K. Kartha was the recipient of both an NRC Merit Award and a Treasury Board of Canada Award of Excellence this year.

Suzanne R. Abrams
Adjunct Professor of Chemistry (University of Saskatchewan)
Lecturer in NRC's Anniversary lecture series
Nesbitt Lecturer (Carleton University)

John Balsevich
Recipient, NRC licensing award, 1991

Gregory Bishop
Recipient, NRC licensing award, 1991

Friedrich Constabel
Adjunct Professor of Applied Microbiology (University of Saskatchewan)
Adjunct Professor of Plant Sciences (University of Alberta)
Editor, Plant Cell Reports

William L. Crosby
Adjunct Professor of Biology (University of Saskatchewan)
Recipient, NRC licensing award, 1991

David I. Dunstan
Adjunct Professor of Biology (University of Calgary)

Fawzy Z. Georges
Adjunct Professor of Biochemistry (University of Saskatchewan)

Jan W.D. GrootWassink
Adjunct Professor of Applied Microbiology (University of Saskatchewan)

Sean M. Hemmingsen
Adjunct Professor of Microbiology (University of Saskatchewan)

Kuo-Nan Kao
Adjunct Professor of Crop Science (University of Saskatchewan)
Fellow of the Royal Society of Canada

Kutty K. Kartha
NRC Merit Award 1991
Invited advisor to Government of India Biotechnology Program
Adjunct Professor of Horticulture (University of Saskatchewan)

Wilfred A. Keller
Adjunct Professor of Crop Science (Universities of Guelph and Saskatchewan)

Wolfgang G.W. Kurz
Recipient, NRC licensing award, 1991
Adjunct Professor of Applied Microbiology (University of Saskatchewan)

Editor, In Vitro Cellular and Developmental Biology

John D. Mahon
Adjunct Professor of Crop Science (University of Saskatchewan)

Louise M. Nelson
Adjunct Professor of Soil Science (University of Saskatchewan)

Gopalan Selvaraj
Adjunct Professor of Crop Science (University of Saskatchewan)

Warren Steck
Member of Senate, University of Saskatchewan

Annex III: Patents and Licenses

1991 Patents

1. "Surface Immobilization of Plant Cells" J. Archambault, B. Volesky and W.G.W. Kurz. Canadian Patent 1,289,902 October 1, 1991.
2. "Method of Solubilizing Potato Starch" R.D. Reichert. Canadian Patent 1,289,094 September 17, 1991.

1991 Licenses

Chemical/Biological Materials Agreements:

1. North Dakota State University for plasmid pBI-426
2. Uniroyal for ABA analogs
3. Noble Foundation for plasmid pBI-426
4. Institute of Genetics and Crop Research, Gatersleben, Germany, for plasmid pBI-426
5. Sakata Seeds America Inc., Salinas, California, for Brassica oleracea var. italica (male parental inbred)
6. Petawawa National Forestry Institute, Chalk River, Ontario for Plasmid CaMV35-TD2
7. Pioneer Hi-Bred International Inc. for Abscisic acid analogs
8. Hawaiian Sugar Planters Association for 35-S pBI-426 with tandem 35-S promotor construct, including AMV translational enhance and GUS:Npt bifunctional reporter gene
9. Rubber Research Institute of Malaysia, Kuala Lumpur, Malaysia, for Abscisic acid analogs for testing antitranspirant action in Hevea
10. Agriculture Research Station, Saskatoon, for plasmids pBI-426 and pBI-505
11. Institute for Application of Atomic Energy, Zheijiang Academy of Agricultural Sciences for Abscisic acid analogs
12. University of Cologne, Germany, for C-DNA clone pTDC5
13. Ag-Canada Reserach Station, Vancouver, B.C. for plasmids pBI-524, 525, 526 and pSynBin 40.
14. Clusius Laboratory, Leiden University, Netherlands, for plasmid pBI-426
15. Centro de Investigacion y de Estudios Avazados del IPN, for plasmids pBI-426, 524, 525 and 526
16. Consiglio Nazionale delle Ricerche, Rome, Italy, for Plasmid pBI-284
17. Saskatoon Cancer Centre for plasmid pSynBin 40
18. Dept of Molecular Biology and Genetics, University of Guelph, for plasmid pBI-524

Annex IV: 1991 Presentations

Adam, L., R.K. Jain, S. Jana and G. Selvaraj. 1991. *Molecular cloning of the betaine aldehyde dehydrogenase cDNA of a halophyte. Third International Congress on Plant Molecular Biology, Tucson, AZ, Oct. 6-12, 1991.*

Baga, M., W.H.R. Langridge and A.A. Szalay. 1991. *Analysis of plant hormone-regulated promoter expression in transgenic tobacco. The 14th International Conference on Plant Growth Substances, Amsterdam, July 21-26, 1991.*

Baga, M., P.L. Dale and A.A. Szalay. 1991. *Expression of luciferase in transgenic tobacco mediated by a promoter element from desiccation tolerant* Craterostigma plantagineum. *The 14th International Conference on Plant Growth Substances, Amsterdam, July 21-26, 1991.*

Baillie, A.M.R., D.J. Epp, W.A. Keller and D. Hutcheson. 1991. In vitro *culture of microspores and regeneration of plants in* Brassica campestris. *8th International Rapeseed Congress, Saskatoon, SK, July 9-11, 1991.*

Barton, D.L. and D.C. Taylor. 1991. *Bioasynthesis of triacylglycerols containing erucic acid in microspore-derived embryos of* Brassica napus. *Poster presented to delegates from GCIRC Rapeseed Congress during tours to PBI's Transgenic Plant Centre, July 7, 1991.*

Bauer-Weston, B., S. Gleddie, J. Webb and W. Keller. 1991. *The production and characterization of Asymmetric somatic hybrids between* Brassica napus *and* Arabidopsis thaliana. *In: Proceedings of Eighth International Rapeseed Congress, Saskatoon, July 9-11, 1991.*

Bekkaoui, F., I. Babic, J.A. Condie, M.M. Moloney and W.L. Crosby. 1991. *Quantitative PCR assessment of expression of two acetolactate genes in* Brassica napus. *Presented to the 20th UCLA Symposium, Keystone, CO; January, 1991; Journal of Cell Biochemistry Supplement 15A: 404,888..*

Bonfils, A.C., S.C. Gleddie, J.A. Webber and W.A. Keller. 1991. *Plant regeneration from all suspension and protoplast cultures of* Capsella bursa-pastoris *(L) medic. In: Proceedings of Eighth International Rapeseed Congress, Saskatoon, July 9-11, 1991.*

Chibbar, R.N., K.K. Kartha, N. Leung, K. Caswell, C.S. Mallard and L. Steinhauer. 1991. *Particle bombardment-mediated genetic transformation of wheat and barley. iSPMB congress on Plant Molecular Biology, Tucson, AR, October 6-11, 1991.*

Cloney, L.P. and S.M. Hemmingsen. 1991. *Chaperonins and rubisco gene expession. Third International Congress on Plant Molecular Biology, Tucson, AZ, Oct. 6-12, 1991.*

Crosby, W.L. 1991. *CFQC television interview for 'FarmGate' program; interviewer, Howard Schmitz; March, 1991.*

Constabel, F. 1991. *Biotechnology and our environment. Canadian Federation of Biological Societies, Kingston, ON, June 9, 1991.*

Constabel, F. 1991. *Plant Biotechnology. NRC, Transgenic Plant Centre, International Rapeseed Congress, Saskatoon, July 15, 1991.*

Constabel, F. 1991. *Plant Biotechnology. Dept. Plant Sciences, University of Alberta, Edmonton, October 22, 1991.*

Constabel, F. 1991. *Plant Biotechnology. Dept. Biology, University of Victoria, Victoria, BC, October 24, 1991.*

Constabel, F. 1991. *Plant biotechnology. Meeting of Extension Service of Saskatchewan Rural Development, Saskatoon, October 1, 1991.*

Datla, R.S.S., B. Bauer-Weston, J. Hammerlindl, C. Bennett, M. Oelck and W. Keller. 1991. *Production of transgenic plants with enhanced levels of resistance to phosphinothricin through insertion of modified PAT gene. Third International Congress on Plant Molecular Biology, Tucson, AZ, Oct. 6-12, 1991.*

Dunstan, D.I., W.L. Crosby and F. Constabel. 1991. *Targeting transgenic trees resistant to insect pests. North American Forest Insect Work Conference, Denver, CO, March 25-28, 1991.*

Dunstan, D.I. 1991. *Somatic Embryogenesis: A Vital Key. Internationa Training Course and Workshop: Techniques and Applications of Biotechnology to Forest Tree Species. Caracas, Venezuela, May 12-24, 1991.*

Dunstan, D.I., W.L. Crosby and F. Constabel. 1991. *Targeting transgenic trees resistant to insect pests. International Energy Agency, Pest/Disease Management Workshop, Ames, IA, August 22-27, 1991.*

Feindel, D.E., P.E. Olsen, L.M. Nelson and C. Van Kessel. 1991 *Polyclonal antibodies for distinguishing amoung* Rhizobium leguminosarum *isolates. 13th North American Symbiotic Nitrogen Fixation Conference, Banff, August 1991.*

Fowke, L.C., M. Tanchak, H. Wang and A. Cutler. 1991. *Protoplasts as tools in cell biology. Physiologia Plantarum 82: A2. Presented at 8th International Protoplast Symposium, Uppsala, Sweden, June 16-20, 1991.*

Georges, F., W.J. Newsted, M. Saleem, A.J. Cutler and S. Polvi. 1991. *Psychromorbidin: A cold inducible, low molecular mass peptide from the snow mold* Coprinus psychromorbidus. *ISPMB, University of Arizona, Tucson, AZ, October 6, 1991.*

Georges, F., W.J. Newsted, M. Saleem, A.J. Cutler, B. Papish and S. Polvi. 1991. *The discovery of an antifreeze-like peptide in snow mold with epitopic homology to the winter flounder AFP. Journal of Cellular Biochemistry 15A: 147. Presented at UCLA Symposium on the genetic dissection of plant cell processes.*

Hemmingsen, S. 1991. *Enzyme organization and cell function. Ventura, California. Gordon Research Conference. January 21-25, 1991.*

Hemmingsen, S. 1991. *Molecular chaperones, protein folding and post-translational gene expression. Department of Physiology, University of Saskatchewan, Saskatoon, SK, February 4, 1991.*

Hemmingsen, S. 1991. *Molecular chaperones, protein folding and post-translational gene expression. University of Regina, Department of Biology, Regina, SK, March 6, 1991.*

Hemmingsen, S. 1991. *Chaperonin proteins and rubisco assembly. The Samuel Roberts Noble Foundation, Inc., Ardmore, OK, April 26, 1991.*

Hemmingsen, S. 1991. *Roles of the alpha and beta polypeptides in chloroplast chaperonin-60. Department of Biology, Texas A & M University, College Station, TX, April 23, 1991.*

Hemmingsen, S. 1991. *Chaperonin proteins and rubisco assembly. Department of Microbiology, University of Saskatchewan, Saskatoon, SK, November 28, 1991.*

Hobbs, S.L.A. 1991. *Developments in pea transformation. John Innes Centre for Plant Science Research, March, 1991.*

Hobbs, S.L.A. 1991. *Characterization of the 5'flanking region of pea seed lipoxygenase genes. NRC Plant Biotechnology Institute, Saskatoon, SK, October, 1991.*

Hogge, L. 1991. *Applications of mass spectrometry in plant biotechnology. Defense Research Establishment Suffield Staff. Medicine Hat, AB, August 19, 1991.*

Hogge, L. 1991. *Applications of continuous flow FAB mass spectrometry in plant biotechnology. Western Canada Mass Spectrometry Users Meeting, Chemistry Department, University of Alberta, Edmonton, AB, November 20, 1991.*

Hogge, L., J.J. Balsevich, D.J.H. Olson, G.D. Abrams, S.R. Abrams and S.L. Jacques. 1991. *Detection of ABA sugar conjugates using packed fused silica capillary LC/MS/MS with reaction mouitoring. International Workshop on Tandem Mass Spectrometry, Lake Louise, AB, November 22, 1991.*

Hudson, J.D., M. Balasubramanian, S. Hemmingsen, and P.G. Young. 1991. cdr2+ *of* Schizosaccharomyces pombe *encodes a novel putative protein kinase. Canadian Society for Cellular and Molecular Biology Symposium, "Growth Control and Cell Cycle Control" Lac Beauport, Quebec.*

Inzé, D., C. Bowler, W. Van Camp, L. Slooten, D. Hérouart, E. Tsang, C. Sybesma and M. Van Montagu. 1991. *Molecular study of oxidative stress in plants. Third International Congress on Plant Molecular Biology Tucson, AZ, Oct. 6-12, 1991*

Kao, H.M., S. Gleddie, W. Keller and G.G. Brown. 1991. *Fusion-mediated synthesis of interspecific* Brassica oleracea/B. napus *hybrids with novel male sterile cytoplasms. In: Proceedings of Eighth International Rapeseed Congress, Saskatoon, July 9-11, 1991.*

Kartha, K.K., R.N. Chibbar, N. Leung, K. Caswell, L. Steinhauer and C.S. Mallard. 1991. *Particle bombardment-mediated genetic transformation of barley and Canadian spring wheat cultivars: Problems and prospects. Symposium on particle bombardment-mediated transformation of plant and animal systems. Madison, WI, March 14-15, 1991.*

Kartha, K.K. 1991. *Genetic engineering of cereals. Invited Seminar, Agriculture Canada Research Station, Swift current, June 10, 1991.*

Kartha, K.K. 1991. *Cryopreservation of plant cells and organs. Lecture given at the Training Course sponsored by the Department of Biotechnology, Government of India and held at the University of Calicut, Kerala State, India, October 12-19, 1991.*

Kartha, K.K. 1991. *Protoplast culture and somatic cell hydridization. Lecture given at the Training Course sponsored by the Department of Biotechnology, Government of India and held at the University of Calicut, Kerala State, India, October 12-19, 1991.*

Kartha, K.K. 1991. *Genetic engineering of crop plants with, special reference to cereals. Lecture given at the Training Course sponsored by the Department of Biotechnology, Government of India and held at the University of Calicut, Kerala State, India, October 12-19, 1991.*

Kendall, E.J. and K.K. Kartha. 1991. *Analysis of wheat plants regenerated from cryoselected callus. 3rd Gordon Conference on Temperature Stress in Plants, Oxnard, CA, January, 1991.*

Kunst, L., D.C. Taylor and E.W. Underhill. 1991. *Molecular genetic analisis of fatty acid elongation in seeds of* Arabidopsis. *Third International Congress of Plant Molecular Biology Tucson, AZ, October, 1991.*

Kunst, L. 1991. *Chromosome walking to* FAE1 *gene. NRC Plant Biotechnology Institute, Saskatoon, May 1991.*

Kunst, L. 1991. *Molecular genetic analysis of plant lipid metabolism: designing fatty acid composition of a seed oil. Department of Botany, University of British Columbia, Vancouver, BC, September, 1991.*

Kunst, L. 1991. *Molecular genetic analysis of plant lipid metabolism: designing fatty acid composition of a seed oil. Biology Department, University of Saskatchewan, Saskatoon, September, 1991.*

Kurz, W.G.W., N.L. Paiva and R.T. Tyler. 1991. *Sanguinarine. 1991 World Congress on Cell and Tissue Culture, Anaheim, CA, June 16-20, 1991.*

Luisdorf, M.M., T.E. Tautorus, S.I. Kikcio and D.I. Dunstan. 1991. *Growth parameters of embryogenic suspension cultures of interior spruce (*Picea glauca-engelmannii *complex) and black spruce (*Picea mariana *mill). 1991 World Congress on Cell and Tissue Culture, Anaheim, CA, June 16-20, 1991.*

Mahon, J.D. 1991. *Molecular biology in plants. Presentation to informational visit by ITA/IRAP representatives. Sept. 18, 1991.*

Mahon, J.D. 1991. *Progress in transformation of pea. The National Pea Improvement Association (U.S.), Lincoln, NE, Nov. 3-5, 1991.*

MacKenzie, S.L. 1991. *Seed Oil Modification at PBI. IMB, Halifax, November 4, 1991.*

Mahon, J.D. 1991. *PBI - Gene Technology. Fourth Biotechnology Program Management and Orientation Meeting, Ste. Adele, PQ, Nov. 6-8, 1991.*

Morales, V.M., J. Taylor and G. Séguin-Swartz. 1991. *Electrophoretic karyotype of the ascomycete* Leptosphaeria maculans. *Sixteenth Fungal Genetics Conference, Asilomar Conference Center, Pacific Grove, CA, March 31 to April 4, 1991.*

Mourad, G.S., B. Pandey, W.L. Crosby and J. King. 1991. *Induction and cloning of a triazolopyrimidine-resistant ALS gene of* Arabidopsis. *International Society for Plant Molecular Biology, Tucson, AZ, October, 1991.*

Nehra, N.S., K.K. Kartha, C. Stushnoff and K.L. Giles. 1991. *Somaclonal variation in strawberry: Effect of hormone concentration and callus age. 8th Meeting of American Society for Horticultural Science, Pennsylvania, July 19-25, 1991.*

Oelck, M.M., C.V. Phan, P. Eckes, D. Donn, G. Rakow and W.A. Keller. 1991. *Field resistance of canola transformants (*Brassica napus *L.) to Ignite (Phosphinotricin). In: Proceedings of Eighth International Rapeseed Congress, Saskatoon, July 9-11, 1991.*

Olson, D. 1991. *New hardware for continuous flow FAB mass spectrometry. Western Canada Mass Spectrometry Users Meeting, Chemistry Department, University of Alberta, Edmonton, AB, November 20, 1991.*

Pomeroy, M.K., S.A. Sparace and W.A. Keller. 1991. *Fatty acid and triacylglycerol biosynthesis in microspore embryos of* Brassica napus. *In: Proceedings of Eighth International Rapeseed Congress, Saskatoon, July 9-11, 1991.*

Rose, P., S. Abrams and L. Gusta. 1991. *Synthesis, resolution and biological activity of 7',7'-difluoroabscisic acid. Poster at the 4th Chemical Congress of North American in New York, August 25-30, 1991.*

Saleem, M., F. Georges, H. Wang and A. Cutler. 1991. *Vectors for antifreeze protein gene expression in plants. ISPMB, University of Arizona, Tucson, AZ, Oct. 6-12, 1991.*

Selvaraj, G. 1991. *Choline metabolism and homeostasis: Molecular biological aspect. Department of Biochemistry, University of Saskatchewan, Saskatoon, SK, November 20, 1991.*

Simmonds, D.H., C. Gervais and W.A. Keller. 1991. *Embryogenesis from microspores of embryogenic and non-embryogenic lines of* Brassica napus. *In: Proceedings of Eighth International Rapeseed Congress, Saskatoon, July 9-11, 1991.*

Taylor, J.L., I.E. Borgmann and G. Séguin-Swartz. 1991. *Molecular genetic differences between isolates of* Leptosphaeria maculans. *GCIRC 8th International Rapeseed Congress, Saskatoon.*

Taylor, J.L., I.E. Borgmann and G. Séguin-Swartz. 1991. *Genetic variability in* Leptosphaeria maculans. *Blackleg Disease Workshop, GCIRC 8th International Rapeseed Congress, Saskatoon.*

Taylor, D.C., L. Kunst and S.M. MacKenzie. 1991. *Bioassembly of storage lipids in oilseed crops; target: trierucin. New Crops Symposium, Indianapolis, IN, October, 1991.*

Walker-Simmons, M.K., R.J. Anderberg and S.R. Abrams. 1991. *(+)S-ABA and (-)R-ABA both block germination, but have different effects on ABA responsive genes in wheat. Third International Congress in Plant Molecular Biology, Tucson, AZ, Oct. 6-12, 1991.*

Weber, N., D.C. Taylor, E.W. Underhill, L.R. Hogge and M.K. Pomeroy. 1991. *Bioassembly of triacylglycerols in microspore embryos of* Brassica napus *L. 8th Arbeitstagung "Pflanzliche Lipide" Wuppertal, Germany, September 10-13, 1991.*

Weber, N. and D.C. Taylor. 1991. *Pflanzliche Zellkulturen und Mikrosporen-embryo - Modelle fur die Biosynthese von Speicherlipiden. 47th Vortragstagung der Deutschen Gesellschaft fur Fettwissenschaft, Braunschweig 1991/Kurzfassung.*

Wilen, R.W., G.J.H. van Rooijen, L.A. Holbrook, S.R. Abrams and M.M. Moloney. 1991. *Relationship between ABA ans osmotic stress in the regulation of storage product gene expression in microspore embryos of* Brassica napus. *Third International Congress on Plant Molecular Biology, Tucson, AZ, Oct. 6-12, 1991.*

Weir, B.J., R.N. Chibbar, R.G. St. Pierre and K.K. Kartha. 1991. *Random amplified polymorphic DNA (RAPD) markers for Saskatoon berry genotype identification. ISPMB congress on Plant Molecular Biology, Tucson, AR, October 6-11, 1991.*

1991/92 Seminar Series

03 April 91: ***Dr. Paul F. Lurquin*** *(Washington State University, Pullman, WA): Herbicide resistance genes and transformation of legumes*

10 April 91: ***Dr. Ravindra N. Chibbar*** *(NRC, Plant Biotechnology Institute, Saskatoon): Gene transfer in cereals - Western style*

24 April 91: ***Dr. Narender Nehra*** *(NRC, Plant Biotechnology Institute, Saskatoon): Plant regeneration and genetic transformation of strawberry*

07 May 91: ***Dr. Michael Pollard*** *(Agrigenetics Company, Madison, WI): Biosynthesis of short- and medium-chain fatty acids*

15 May 91: ***Dr. Ljerka Kunst*** *(NRC, Plant Biotechnology Institute, Saskatoon): Chromosome walking*

20 June 91: ***Dr. Serge Bellier*** *(JEOL, Montreal): JEOL - NMR Instruments and capabilities*

04 September 91: ***Dr. Michael Fromm*** *(Monsanto, St. Louis, MO): Production of transgenic corn plants*

18 September 91: ***Dr. Stephen Rothstein*** *(Dept. of Molecular and General Genetics, University of Guelph, Guelph, Ontario): Production of transgenic tobacco plants having altered levels of peroxidase activity and effects on phenotype*

02 October 91: ***Dr. Shaun Hobbs*** *(NRC, Plant Biotechnology Institute, Saskatoon): Characterization of the 5' flanking region of genes coding for pea seed lipoxygenases*

16 October 91: ***Dr. George Haughn*** *(Department of Biology, University of Saskatchewan, Saskatoon): Inside-out flowers: the molecular genetics of flower development in* Arabidopsis

30 October 91: ***Dr. Ben Sutton*** *(Forest Biotechnology Center, B.C. Research Corporation, Vancouver, B.C.): Development of RFLP markers for the analysis of spruce introgression and studies of seed storage protein genes of spruce*

13 November 91: ***Dr. Lynn Cloney*** *(NRC, Plant Biotechnology Institute, Saskatoon): Analysis of* B. napus *chaperonins*

20 November 91: ***Dr. Luc Adam*** *(NRC, Plant Biotechnology Institute, Saskatoon): Studies of salt stress inducible genes in* Kochia scoparia

27 November 91: ***Dr. Victor Morales*** *(NRC, Plant Biotechnology Institute, Saskatoon): The use of molecular genetics in the study of the phytopathogenic fungus* Leptosphaeria maculans

04 December 91: ***Dr. Michael F. Tomashow*** *(Department of Crop and Soil Sciences, Michigan State University, East Lansing, MI): Molecular genetics of cold acclimation in* Arabidopsis thaliana

16 December 91: ***Dr. Dwight T. Tomes*** *(Pioneer Hi-Bred Int., Johnston, IA): Producing and evaluating transgenic plants/seed containing genes of use to agriculture*

15 January 92: ***Dr. Alan McHughen*** *(Department of Plant Science, University of British Columbia, Vancouver, BC): Agrobacterium mediated transformation in linseed flax*

30 January 92: ***Dr. Maurice M. Moloney*** *(Department of Biology, University of Calgary, Calgary, Alberta): Regulation of gene expression during the development of gametophytic and zygotic embryos in Brassica*

12 February 92: ***Dr. Patricia Rose*** *(NRC, Plant Biotechnology Institute, Saskatoon): ABA-logs: Molecular tools for probing ABA responses*

19 February 92: ***Dr. Mohammed Eweida*** *(NRC, Plant Biotechnology Institute, Saskatoon): Gene expression strategies of potato virus X*

26 February 92: ***Dr. Monica Båga*** *(NRC, Plant Biotechnology Institute, Saskatoon): A functional analysis of the plant hormone-regulated mannopine synthase promoters*

18 March 92: ***Dr. Ron Depauw*** *(Agriculture Canada Research Station, Swift Current, SK): Future trends in wheat breeding*

Annex V: Participation on Committees

In-house committees:

The Planning & Review Committee is the premier PBI committee, consisting of managers and all research and support group leaders. Member in 1991/92 were Suzanne Abrams, Adrian Cutler, Fred Constabel (chair), Bill Dean, David Dunstan, Bob Giroux, Sean Hemmingsen, Kutty Kartha, Wilf Keller, Wolf Kurz, Samuel MacKenzie, John Mahon, Gopalan Selvaraj and Warren Steck (ex-officio). Secretary was Rosemarie Gallays.

Computer Committee: The group's role is to advise on future needs for computer systems. Members at year end were Adrian Cutler (chair), Bob Giroux, Harry Holfeld, Samuel MacKenzie, Martin Lapp and Mohamed Eweida.

Library Committee: This committee assists the on-site plant biotechnology branch of the Canada Institute for Scientific and Technical Information (CISTI) in choosing book and journal orders which match current project needs in the Institute. Members at year end were: Monika Baga, Flora Chen, Dr. Fred Constabel, Jan GrootWassink, Sean Hemmingsen, Victor Morales (chair) and Patricia Rose.

Safety and Health Committee: The group is part of NRC's overall organizational network for workplace safety and health. It advises on potential risks, and has responsibilities in hazards procedures and in first aid training for staff. Janet Condie, Brock Chatson, Bill Dean, Bob Giroux, Janet Taylor, John Magus and Terry Bethune.

Special Events Committee: This group assists in organization of major events at the Institute. Year-end membership was: Dave Baliski, Greg Bishop, Janet Condie, Rosemarie Gallays (chair), Eugen Kurylo and Janice Schmidt.

Research and Development Committees:

Suzanne R. Abrams
Board of Directors, Ag-West Biotech

John Balsevich
Saskatchewan chairman, CIC Awards Committee

Friedrich Constabel
Member of Review Committees for
Forestry Canada (Petawawa National Forestry Institute)
Institut de recherche en biologie végétale
Agriculture Canada (Saskatoon Research Station)
NRC Information Management Committee
Chairman, PBI Planning and Review Committee

K. William Dean
ASHRAE Research Canada: President
Consultant, Research Promotion Committee
Research Officer, Cold Climate Design Task Group

David I. Dunstan:
Advisory Committee/Biosciences (Saskatchewan Institute of Applied Science and Technology)

Kutty K. Kartha
NRC representative on Canadian Agricultural Research Council

Wilfred A. Keller
Advisory committees of Agriculture Canada
Saskatoon Research Station
Plant Research Centre (Ottawa)

Wolfgang G.W. Kurz
PBI representative on NRC Biotech Contributions Program

John D. Mahon
NRC member on Advisory Committee to the Saskatchewan Crop Development Centre

Louise M. Nelson
Co-chair, organizing committee for 13th North American Symbiotic Nitrogen Fixation Conference, 1991

Warren Steck:
NRC Committee of Directors General; Human Resources Committee
PBI Advisory Board
Advisory Council, U of Saskatchewan College of Agriculture
Member of Forestry Canada/NRC joint steering committee
Member of Canadian National Commission for CASAFA
NRC member on Canadian Agricultural Services Coordinating Committee

Annex VI: Personnel

Staff, guest researchers and affiliates

PBI's staff are employees of the National Research Council. Guest Researchers are employees of (or sponsored by) other organizations who carry out research or receive training on the Institute's premises. Affiliated Scientists are non-NRC collaborating scientists who are being recognized through this title as leading colleagues in Canadian plant biotechnology.

Staff of the Institute 1991/92

An asterisk (*) indicates a limited-term staff appointment.

Some staff were not present for the entire year.

Director General:
Warren F. Steck, *B.Eng. (McGill); Ph.D. (Saskatchewan)*

Director of Research:
Friedrich Constabel, *Dr. Res. Nat. (Göttingen), Dr. Habil. (Bonn)*

Operations Manager:
Robert Giroux, *B.Comm. (Ottawa)*

Facilities Coordinator:
K. William Dean, *B.Eng. (Saskatchewan), P.Eng.*

Principal Research Officers:
Wolfgang G.W. Kurz, *Ph.D. (Vienna)*
Wilfred A. Keller, *B.S.A., Ph.D. (Saskatchewan)*

Senior Research Officers:
Suzanne R. Abrams, *B.Sc. (Carleton), Ph.D. (Dalhousie)*
William L. Crosby, *B.Sc. (British Columbia), Ph.D. (Heriot-Watt)*
David I. Dunstan, *B.Sc. (London), Ph.D. (NE London Polytechnic)*
Kuo-Nan Kao, *B.S. (Chung-Hsing), M.S.A. (Guelph), Ph.D. (Saskatchewan), F.R.S.C.*
Kutty K. Kartha, *B.Sc. (Saugar), M.Sc. (Jawaharlal), Ph.D. (New Delhi)*
Samuel L. Mackenzie, *B.Sc., Ph.D. (Edinburgh)*
John D. Mahon, *B.Sc.(Western Ontario), M.Sc., Ph.D. (Queen's)*
Louise M. Nelson, *B.Sc. (Western Ontario), Ph.D. (Calgary)*

Associate Research Officers:
John J. Balsevich, *B.Sc., M.Sc., Ph.D. (British Columbia)*
Ravindra N. Chibbar, *B.Sc., M.Sc. (Meerrut), Ph.D. (Panjab), Ph.D. (Western Ontario)*
Adrian J. Cutler, *B.Sc. (Wales), Ph.D. (Florida State)*
Raju S. Datla*, *B.Sc., M.Sc., Ph.D. (Andhra)*
Fawzy Georges, *M.Sc. (Brock), Ph.D. (Ottawa)*
Jan W.D. Grootwassink, *B.Sc., M.Sc. (Wageningen), Ph.D. (Calgary)*
Sean M. Hemmingsen, *B.Sc. (British Columbia), Ph.D. (Queen's)*
Shaun L.A. Hobbs, *M.A. (Cambridge), B.A., D. Phil. (Oxford)*
Martin S. Lapp, *B.Sc., M.Sc. (York), Ph.D. (Alberta)*
M. Soledade C. Pedras*, *B.Sc., M.Sc. (Porto), Ph.D. (Alberta)*
Lawrence E. Pelcher, *B.S. (Aquinas), M.S., Ph.D. (Michigan State)*
Gopalan Selvaraj, *B.Sc. (Bangalore); M.Sc., Ph.D. (Carleton)*
Janet L. Taylor, *B.Sc. (Iowa State), Ph.D. (Washington State)*

Assistant Research Officers:
Larry Holbrook*, *B.Sc., M.Sc., Ph.D. (Toronto)*
Ljerka Kunst, *B.Sc., M.Sc. (Zagreb), Ph.D. (Michigan)*
David C. Taylor, *B.Sc., Ph.D. (Carleton)*
Edward W.T. Tsang, *B.Sc., M.Sc., Ph.D. (Saskatchewan)*

Visiting Research Officers:
Mohammed Saleem*, *B.Sc., M.Sc. (Pakistan), M.Sc. (Laurentian), Ph.D. (Western Ontario)*
Ulrich Seitz*, *Ph.D. (Tubingen)*

Research Associates:
Luc Adam*, *B.Sc., Ph.D. (Laval)*
Monica BAGA* B.Sc., *Dr. Med. Sci. (Umea)*
Alison Baillie*, *B.S.A., M.Sc. (Manitoba), Ph.D. (Saskatchewan)*
Faouzi Bekkaoui*, *B.Sc. (Berkane), M.Sc.(Tours), Ph.D. (Paris)*
Resham Bhalla*, *B.Sc., M.Sc., (Manitoba), Ph.D (Ottawa)*
Venkat Bommineni*, *B.Sc., M.Sc., (Andhra Pradesh), Ph.D. (Western Ontario)*
Lynn Cloney*, *B.Sc., Ph.D. (New Brunswick)*
Jin-Zhuo Dong*, *B.Sc. (Hebei), M.Sc.(Shenyang), Ph.D. (Beijing)*
Mohamed Eweida*, *B.Sc., (Alexandria), M.Sc., Ph.D. (Uppsala)*
Mark C. Jordan*, *B.Sc. (Guelph), M.Sc. (Manitoba), Ph.D. (Saskatchewan)*
Edward J. Kendall*, *B.Sc., M.Sc. (Dalhousie), Ph.D. (Guelph)*

Victor Morales, B.Sc. (Columbia), M.Sc., Ph.D. (Florida)*
Narender Nehra, B.Sc., M.Sc., (Haryana, India), Ph.D. (Saskatchewan)*
***M. Soledade C. Pedras,** B.Sc., M.Sc. (Porto), Ph.D. (Alberta)*
Michel Perras, B.Sc. (Montreal), M.Sc. (Quebec), Ph.D. (Montreal)*
Gilles Pilate, B.Ed., M.Sc., Ph.D. (Paris)*
Hans Rempel, B.Sc. (California State), Ph.D. (California)*
Patricia Rose, B.Sc., Ph.D. (Alberta)*
Hong Wang, B.Sc. (Central China), M.Sc. (British Columbia), Ph.D. (Saskatchewan)*
Huacheng Wu, B.S., M.S. (Xiamen), Ph.D. (Iowa)*

Laboratory Technical Officers:
***Maureen Anderson,** B.Sc (Saskatchewan)*
***David Baliski,** B.S.T. (K.I.A.A.S.)*
***Carla Barber,** B.Sc. (Saskatchewan)*
Dennis Barton, B.Sc. (Saskatchewan)*
Brian Beck, B.Sc. (Carleton)*
***Diana Bekkaoui,** B.S.A. (Saskatchewan)*
***Terry Bethune,** B.Sc. (Saskatchewan)*
***Greg Bishop,** B.Sc. (Saskatchewan)*
***Cheryl Bock**, B.Sc. (Saskatchewan)*
***Karen Caswell,** B.S.A., M.Sc. (Saskatchewan)*
***K. Brock Chatson** , C.R.T. (S.A.I.T.)*
***Maxine Coffey,** B.L.T. (Regina)*
***Janet Condie,** B.Sc. (Queen's)*
Michelle Cowell, B.Sc. (Saskatchewan)*
Gerald Davies, B.Sc. (Winnipeg)*
***Catherine Delong,** B.S.A., B.Sc. (Saskatchewan)*
Don Dymond
Gina Feist, B.Sc. (Saskatchewan)*
Laurie Friesen, B.Sc., M.Sc. (Saskatchewan)*
Michael Giblin
Joseph Hammerlindl
***Rozina Hirji,** B.Sc. (Makerere)*
***Lawrence Hogge,** C.R.T. (S.A.I.T)*
Shufen Hou*
***David Horn,** B.S.T. (K.I.A.A.S.)*
Connie Knapp
***Allen Kolenovsky,** B.Sc. (Saskatchewan)*
***Eugen Kurylo,** B.Sc. (Regina)*
Deborah Lashta B.Sc. (Saskatchewan)*
***Nick Leung,** B.Sc. (Saskatchewan)*
***Mary Loewen,** B.S.A. (Saskatchewan)*
Cliff Mallard
***John Magus,** B.Sc.(Saskatchewan)*
Morris Michayluk
Jacek Nowak
***Doug Olson,** B.S.T. (K.I.A.A.S.)*
***Keith Pahl,** B.S.T. (K.I.A.A.S.)*
Barry Panchuk
***Bob Papish,** B.Sc. (Saskatchewan)*
Eric Pass, B.Sc. (Guelph)*
***Sandra Polvi,** B.S.T. (K.I.A.A.S.)*
Meiqin Qi, B.Sc. (Mongolia), M.Sc. (Saskatchewan), Ph.D. (British Columbia)*
***Darwin Reed,** B.Sc. (Saskatchewan)*
Janice Schmidt, B.Sc. (Saskatchewan)*
***Peter Schorr,** B.S.T. (N.A.I.T.)*
***Don Schwab,** B.S.T. (K.I.A.A.S.)*
***Angela Shaw,** B.Sc. (Saskatchewan)*
Jerry Shyluk
***Lee Steinhauer,** B.A. (Saskatchewan)*
Marvin Swartz, B.Sc., M.Sc. (Guelph)*
***Don Tenaschuk,** B.Sc. (Saskatchewan)*
Tom Warkentin, B.S.A., M.Sc. (Manitoba), Ph.D. (Saskatchewan)*
Hannah Wu, B.Sc., M.Sc. (Xiamen), Ph.D. (Iowa)*

Administrative Services:
Gwen Brassard*
Gayle Berry
Debbie McLeod
Kathryn Seabrook
Carol Walker
Katherine Wilson

Computer Services:
Harry Holfeld
Wayne Stankewich

Supply Services:
Olga Coates
Irene Howe
Peter Keating*
Cheryl Rygh

Facilities Services:
Bill Brumwell
Bill Dean
Armand Fendelet
Rick McDonald
George Reynolds

Publications And Events:
Rosemarie Gallays

Summer Students 1991:
Brian Beck (Saskatchewan)*
Ira Borgmann (Saskatchewan)*
Denis Bosc (Manitoba)*
Rowina Chow (Waterloo)*
Suzanne JAcques (McGill)*
Ebba Kurz (Queens)*
Jeri Lim (Simon Fraser)*
Melissa Long (Calgary)*
Ronan O'Hagan (Manitoba)*
Susan Scutchings (Saskatchewan)*
Richard Weger (Alberta)*
Marni Wesner (Saskatchewan)*

Affiliated Scientists of the Institute 1991/92:

Helmut Bertrand, *B.A., M.Sc., Ph.D. (Kansas), Professor of Microbiology, Guelph University*

Normand Brisson, *B.Sc., M.Sc. (Montreal), Ph.D. (McGill), Professor of Biochemistry, University of Montreal*

Keith Downey, *B.Sc., M.Sc., (Saskatchewan), Ph.D. (Cornell), head, Oilseeds Section, Agriculture Canada Research Station (Saskatoon, Sask.)*

Brian Ellis, *Ph.D. (British Columbia), Professor and Head, Department of Plant Science, University of British Columbia*

Lawrence Fowke, *Ph.D. (Carleton), Professor of Biology, University of Saskatchewan*

Bryan L. Harvey, *B.S.A., M.Sc., (Saskatchewan), PhD (California), Professor of Crop Science and Plant Ecology, University of Saskatchewan; and Director of the Saskatchewan Crop Development Center*

George Haughn, *B.Sc. (Dalhousie), Ph.D. (Cornell), Professor of Biology, University of Saskatchewan*

Bryan McKersie, *Ph.D. (Waterloo), Director of the Plant Biotechnology Centre, Guelph University*

Brian Miki, *B.Sc.(Carleton), Ph.D. (Toronto), Plant Research Centre, Agriculture Canada*

Maurice Moloney, *B.Sc.(London), Ph.D. (Leicester), Professor of Biology, University of Calgary*

Ann Oaks, *B.A., M.A. (Toronto), Ph.D. (Saskatchewan), Professor of Biology, Guelph University*

Trevor A. Thorpe, *B.Sc. (Allahabad), B.Sc., Ph.D. (California), Professor of Biology, University of Calgary*

Guest Researchers at the Institute 1991/92:

Dr. Garth Abrams, *Crop Development Centre*

Dr. Robert Adams, *Baylor University (USA)*

Mr. Philippe Antoine, *U. Claude Bernard (Paris)*

Mr. Darryl Arsenault, *Saskatchewan Wheat Pool*

Mr. Perry Aulie, *Prairie Plant Systems Inc.*

Mr. Vivijan Babich, *University of Saskatchewan*

Mr. Roberto Bacchetto, *NeoPhyte Inc.*

Dr. Alison Baillie, *Canola Council of Canada*

Dr. M. Balasubramanian, *University of Saskatchewan*

Dr. Vipan K. Bansal, *Agriculture Canada*

Ms. Gwen Bassard, *Kelly Services*

Mr. Dennis Barton, *Pioneer Hi-Bred*

Ms. Brigitte Bauer-Weston, *Hoechst Canada Inc.*

Dr. Harindra Balyan, *University of Meerut (India)*

Mr. Brian Beck, *Manpower Temporary*

Ms. Colleen Bennett, *Hoechst Canada Inc.*

Mr. Mike Bernardy, *Agriculture Canada*

Dr. Joe Boothe, *University of Alberta*

Ms. Leslie Boyd, *University of Saskatchewan*

Ms. Kelly Bromm, *Hoechst Canada*

Mr. Robin Browne, *University of Saskatchewan*

Ms. Shirley Brylinski, *Kelly Services*

Ms. Mei Chen, *Prairie Plant Systems Inc.*

Mr. H. Cheng, *Genetic Institute of Jiangsu Academy of Agricultural Sciences, Nanjing (China)*

Ms. Deanne Chenier, *University of Saskatchewan*

Mr. Blain Chartrand, *Prairie Plant Systems Inc*

Mr. Ajay Chevell, *NeoPhyte Inc.*

Ms. Mi Chung, *Kyung Hee Univeristy*

Ms Mary Collican, *Heinze Institute*

Ms. Michelle Cowell, *Philom Bios Inc*

Mr. Keith Coldwell, *Canola Council of Canada*

Ms. Diana Collins, *NeoPhyte*

Mr. Jim Cunningham, *Philom Bios Inc.*

Dr. Raju Datla, *Hoechst Canada*

Mr. Jean Depoisier, *U. Claude Bernard (France)*

Ms. Nina Desjardines, *University of Saskatchewan*

Dr. Malcolm Devine, *University of Saskatchewan*

Mr. Nabil El-rouby, *University of Saskatchewan*

Mr. Delwin Epp, *Canola Council of Canada*

Ms. Cheryl Evans, *Hoechst Canada*

Mr. David Feindel, *University of Saskatchewan*

Ms. Jill Forrester, *Manpower Temporary*

Mr. Armel Gallet, *Région Rhône-Alpin (France)*

Mr. Jarrod Gatzke, *Hoechst Canada*

Mr. Stephane Germain, *Université Claude Bernard (France)*

Mr. Ted Gerwing, *Hoechst Canada*

Ms. Laverne Goodman, *Saskatchewan Wheat Pool*

Dr. Sue Grayson, *MicroBio Rhizogen Inc*

Dr. Larry Gusta, *Crop Development Centre*

Ms. Linda Hall, *University of Saskatchewan*

Ms. Cheryl Hampson, *University of Saskatchewan*

Dr. George Haughn, *University of Saskatchewan*

Mr. Les Hoffman, *self-funded*

Dr. Larry Holbrook, *NeoPhyte Inc.*

Ms. LeeAnn Holmes, *Manpower Temporary*

Mr. Rahim Honarnejad, *Gilan University (Iran)*

Dr. Atta Hussain, *University of Saskatchewan*

Mr. Ravinder Jain, *University of Saskatchewan*

Ms. Grace Johnson, *Saskatchewan Wheat Pool*

Dr. H.M. Kao, *Hoechst Canada Inc*

Mr. Raman Kapur, *University of Saskatchewan*

Mr. Apostolos Karoutis, *University of Saskatchewan*

Mr. Nabil Khedranwar, *United Nations Development Program*

Ms. Susan Kikcio, *BC Research*

Mr. Colin Kindrachuk, *University of Saskatchewan*

Dr. John King, *University of Saskatchewan*
Mr. Ed Knapp, *self-funded*
Ms. Diane Knight, *MicroBio Rhizogen*
Ms. Cherie Koster, *SIAST*
Ms. Gloria Kostyniuk, *Kelly Services*
Ms. Cathy Kujack, *Philom Bios Inc.*
Dr Nancy Lamb, *University of Saskatchewan*
Mr. Sun Lee, *Kyung Hee University (Korea)*
Ms. Mary Leggett, *Philom Bios Inc.*
Mr. Bo Lei, *Pioneer Hi-Bred*
Jiyue Liu, *University of Saskatchewan*
Yu Lee Liu, *University of Saskatchewan*
Ms. Lisa Lukowich, *Kelly Services*
Dr. Monika Luisdorf, *BC Research*
Mr. Nick Makohon, *Kelly Services*
Ms. Marilyn Martin, *University of Saskatchewan*
Ms. Linda Mcgregor, *Saskatchewan Wheat Pool*
Mr. Satya Miranpuri, *Manpower Temporary*
Ms Maria Moore, *Weyerhaeuser Canada Ltd*
Ms. Jenette Muth, *Manpower Temporary*
Mr. Ramesh Nair, *University of Saskatchewan*
Mr. N. Nehra, *University of Saskatchewan*
Mr. Y. Niu, *University of Saskatchewan*
Mr. Charles Ntiamoah, *University of Saskatchewan*
Ms. Laurel O'Connor, *Philom Bios Inc*
Ms. Karen Oddie, *Queen's University*
Dr. Michael Oelck, *Hoechst Canada Inc.*
Dr. Brian Orshinsky, *Saskatchewan Wheat Pool*
Mr. Don Palmer, *University of Manitoba*
Mr. Norman Pateman, *Heinz Institute*
Ms. Sherilyn Phelps, *University of Calgary*
Ms. Isabelle Poisson, *MicroBio Rhizogen*
Ms. Elizabeth Prusinkiewicz, *Philom Bios*
Ms. Cindy Pryma, *Manpower Temporary*
Mr. Om Rajora, *Ag. Development Fund*
Mr. J. Ramamoorthy, *University of Saskatchewan*
Mr. Dubravka Rasol, *University of Zagreb, (Yugoslavia)*
Mr. Martin Reaney, *University of Saskatchewan*
Mr. Charlene Reiner, *Hoechst Canada*
Ms. Mondee Redman, *NeoPhyte*
Ms. Angie Salter, *Prairie Plant Systems Inc.*
Ms. Reena Sargunar, *University of Saskatchewan*
Ms. Connie Sauder, *Kelly Services*
Mr. Kevin Seabrook, *Kelly Services*
Dr. Peter Shargool, *University of Saskatchewan*
Mr. Peter Schorr, *NeoPhyte Inc.*
Ms Susan Scutchings, *University of Saskatchewan*
Ms. Uta Seitz, *self-funded*
Dr. George Slater, *University of Saskatchewan*
Mr. Michael Snow, *Kelly Services*
Dr. Earl St.Denis, *(contract holder)*
Ms. Christine Stewart, *Prairie Plant*
Ms. Cheryl Tautorus, *University of Saskatchewan*
Mr. Tom Tautorus, *Stange Canada Inc.*
Dr. Ole Thangstad, *University of Trondheim, Norway*
Mr. Mike Thompson, *University of Calgary*
Dr. Robert Tyler, *University of Saskatchewan*
Dr. Ted Underhill, *self-funded*
Dr. Chris Vankessel, *University of Saskatchewan*
Dr. Hong Wang, *University of Saskatchewan*
Ms. Cherylynn Walters, *Prairie Plant Systems Inc.*
Mr. Tom Warkentin, *University of Saskatchewan*
Mr. Brian Weir, *University of Saskatchewan*
Ms. Irene Wiens, *University of Saskatchewan*
Ms. Adrienne Woytowich, *University of Saskatchewan*
Jia Xie, *Philom Bios Inc*
Mr. Jing Yi Yang, *Westech Agriculture*
Dr. Xiang Yin, *Prairie Malt Ltd.*
Dr. Ming Ye, *Westech Agriculture*
Mr. Brent Zetti, *Prairie Plant Systems Inc*
Mr. Xuimei Zhang, *Prairie Plant Systems Inc*

Associated Laboratory:

The Forest Biotechnology Centre of BC Research Corporation
(3650 Wesbrook Mall, UBC Campus, Vancouver)

Director of the Centre:
Ben Sutton, *B.Sc., M.Sc., Ph.D. (British Columbia)*

The Forest Biotechnology Centre (FBC) became an associated laboratory of the NRC in 1990. The Centre, established in 1987 to apply biotechnology to the problems of reforestation and tree improvement, conducts research in four areas: molecular genetics, tissue culture, microbial inoculants and ecophysiology.

FBC applies molecular genetics to the analysis of wild populations and selected trees in tree breeding programs. This information can be used in measuring hybridization and in selecting seed sources appropriate for areas to be reforested. Our tissue culture research accelerates the introduction of improved seed through effective mass propagation techniques and to the development of clonal forestry. Microbial inoculants research isolates strains which can provide disease control and root growth promotion of conifer seedlings. At FBC the principles of ecophysiology are being applied to assess seedling quality in existing and modified seedling production protocols, and to assess the quality of somatic-embryo-derived plants.

Plant Biotechnology Institute

Annual Expenditures and Revenue

(Thousands of dollars)	1991-92	1990-91
Expenditures		
Wages and Employee Benefits	6,263	7,032
Other Operating	3,706	3,895
Capital	1,609	715
Total Expenditures	**11,578**	**11,642**
Revenue	**227**	**187**

Additional Financial Information

(Thousands of dollars)	1991-92
Applicable Corporate Overhead	2,037
Buildings (Historical Cost)	7,745
Equipment (Historical Cost)	215,698